JUN 1 8 1982

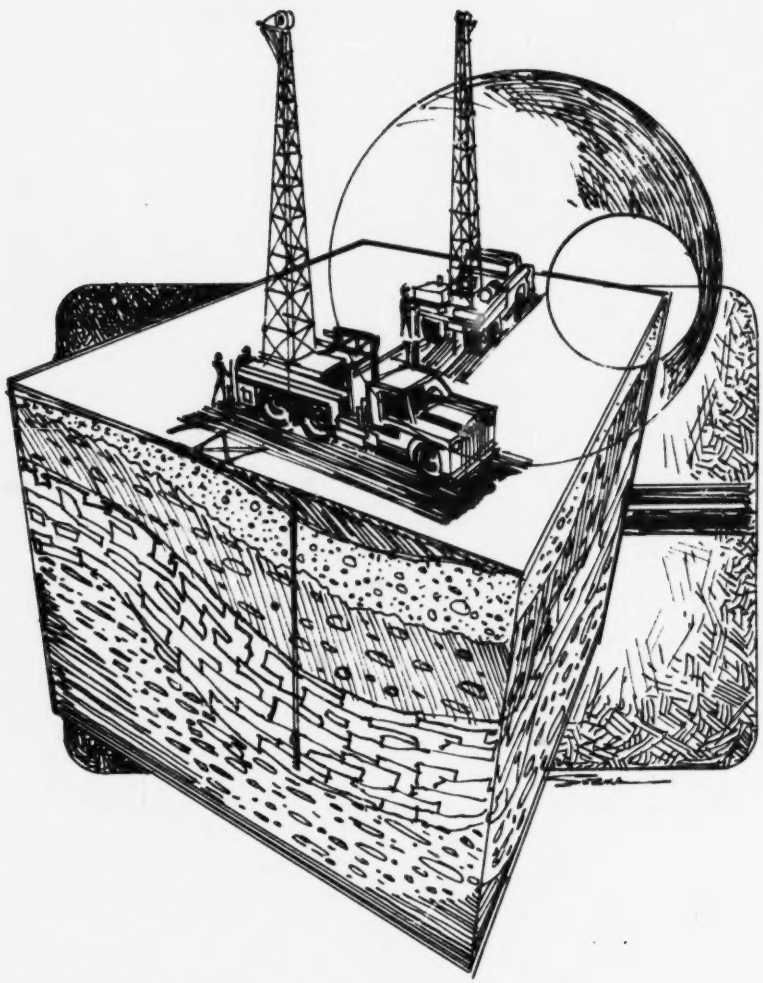
660

I 27.2: G 29/3

ORIGINAL

GEOLOGY FOR DESIGNS AND SPECIFICATIONS

OF THE ASSISTANT COMMISSIONER ENGINEERING AND RESEARCH



COMPLETED

211

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY
FOR
DESIGNS AND SPECIFICATIONS
OF THE
ASSISTANT COMMISSIONER - ENGINEERING AND RESEARCH

DIVISION OF GEOLOGY
ENGINEERING AND RESEARCH CENTER
DENVER, COLORADO

DECEMBER 1981

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

I

FOREWORD

This guide has been compiled from the Division of Geology memorandum series and from recommendations presented at the 1981 meeting of Bureau geologists. It discusses the geologic requirements for designs and specifications prepared by the ACER (Assistant Commissioner - Engineering and Research) with the intent of establishing common guidelines, procedures, and concepts for the collection, evaluation, and presentation of geologic information for ACER specifications. The preparation of designs and specifications and effective construction monitoring require consistent, comprehensive, and timely geologic information. The guide has been prepared for use by all Bureau geologists. With these guidelines being used by Bureau geologists, the collection and documentation of geologic information will be more uniform, and the required evaluations and discussions will be better defined. This uniformity and definition will promote integration and coordination of geology with design and construction activities.

It is hoped that this guide can form the basis of an exchange of ideas which will be mutually beneficial to all Bureau geologists. Suggestions and comments on the content and methods discussed are encouraged and solicited. Many of the comments received previously were incorporated in this edition. Other excellent comments and suggestions will be incorporated in future revisions. Section 5, which standardized descriptors for geologic features, represents a general consensus of terminology but is far from complete. However, additional review of these descriptors and the addition of other categories is required to promote more uniform, more complete, and quantitized descriptors. Updating of the guide will occur whenever sufficient revisions and additions become available.

Experienced geologists will find useful reminders about new procedures and special techniques, while the newer employees can look upon the guide as an opportunity to expand their familiarity with geology as practiced in the Bureau of Reclamation.

Many checklist items in Section 4, Collection of Geologic Information, are adapted from California Division of Mines and Geology Notes, No. 44.

Jerry S. Dodd
Chief, Division of Geology

GLOSSARY

ACER - Assistant Commissioner - Engineering and Research
E&R - Engineering and Research
DC - Denver Construction
GI - General Investigations

The following terms are from the ACER Specifications Schedule computer program:

AWARD	- Date contract is to be awarded
DATA	- Date on which design data are to be submitted to ACER by the region or project
GEOLOGY or DATA-G	- Date on which geologic design data are to be submitted to ACER from the region or project
IFB	- Invitation for bid date
SPECB	- Specifications Branch date or Division of Design Release Date (specifications prepared and ready for typing)

CONTENTS

Section		Page
	Foreword	i
	Glossary	ii
1	Basic Concepts for Engineering Geology Programs	1-1
2	Definitions of Basic Geologic Terms	2-1
3	Milestone Geologic Documents for Bureau of Reclamation Designs and Specifications of the Assistant Commissioner - Engineering and Research	3-1
	Engineering Geology Review Memorandum	3-1
	Geologic Design Data Report	3-3
	Specifications Paragraphs and Drawings	3-4
	Geologic Design Summary and Construction Considerations Memorandum	3-4
	Requirements for Geology During Construction Memorandum	3-5
	Construction Geology Report	3-5
4	Collection of Geologic Information	4-1
5	Terminology for the Description of Physical Properties of Earth Materials	5-1
	General	5-1
	Surficial Deposits	5-1
	Bedrock	5-2
	Descriptors for Physical Characteristics of Bedrock	5-3
	Lithology	5-3
	Hardness-Strength	5-6
	Weathering	5-8
	Discontinuities	5-10
	Instructions for the Description of Shear and Fault Zones	5-13
	Uniform and Zoned Shears	5-13
	Descriptors and Descriptions of Shears	5-15
6	Interpretation and Presentation of Geologic Design Data	6-1

CONTENTS - Continued

Section		Page
7	Checklist for Engineering Geology Considerations	7-1
	Geomechanical Element	7-1
	Stability of Earth Materials	7-1
	Deformability of Earth Materials	7-3
	Geologic Fluids Element	7-4
	Ground-water Occurrence and Behavior	7-4
	Other Fluid Occurrence and Behavior	7-5
	Geochemical and Geothermal Element	7-5
	Geologic Hazards Element	7-6
	Environmental Element	7-7
8	Reservoir Site Geologic Studies	8-1
	Introduction	8-1
	Basic Requirements for Reservoir Geologic Maps and Studies	8-2
	Methods of Investigations	8-4
	Geomorphologic Interpretation	8-5
	Hydrogeologic Studies	8-5
	Subsurface Investigations	8-6
	Remote Sensing	8-6
	Collection and Presentation of Data	8-7
	Distribution of Bedrock and Surficial Deposits	8-7
	Discontinuities and Structural Features	8-7
	Ground-water Occurrence and Behavior	8-8
	Mineral Resources	8-8
	Observed and Potential Geologic Hazards	8-8
	Buried Conduits	8-8
	Landslides and Rim Stability	8-8
	Reservoir Integrity and Potential Leakage	8-9
	Sources of Contamination of Reservoir Water	8-9
	Reservoir Characteristics	8-9
	Reservoir Rim Stability and Landslide Classification	8-10
	Group A, Active Slide Areas	8-11
	Group I, Slide Areas Inactive for at Least the Last 10 Years	8-12
	Group P, Potential Slide Areas	8-13
	Group F, Rockfall Areas	8-13

CONTENTS - Continued

Section		Page
	Reservoir Water-holding Capability	8-13
9	Geologic Design Data Report	9-1
	Submittal of the Report	9-1
	General Comments on the Report	9-3
	Content of the report	9-3
	Drawings	9-4
	General outline	9-4
	Comments on general outline	9-6
10	Signatory Authority and Signature Blocks for Geologic Drawings	10-1
	Signatory Authority for Drawings	10-1
	Signature Blocks	10-2
11	Use of Unified Soil Classification System for Geologic Exploration	11-1
	General	11-1
	Use of SI Units	11-1
	Graphic Symbols	11-2
	Descriptive Information Criteria	11-2
	Typical Names	11-9
	Use of the Unified Soil Classification System as a Secondary Identification Method for Materials Other Than Natural Soils	11-11
	Special Cases for USCS Classification	11-14
	Format of Word Descriptions for Test Pits and Auger Hole Logs	11-15
	Format of Word Descriptions on Test Pit and Auger Hole Logs for Soils with Cobbles and Boulders	11-17
	Format of Word Descriptions for Drill Hole Logs	11-18
	Examples of Word Descriptions	11-22
12	Standards for Care, Retention, and Disposal of Drill Core and Subsurface Soil and Rock Samples	12-1
	General	12-1
	Location and Stages of Storage	12-2
	Conditions of Storage	12-4
	Length of Storage	12-5
	Disposal of Core and Samples	12-8
	Retention of Rock Core Samples	12-9
	Boxing and Labeling of Drill Core for Storage	12-10

CONTENTS - Continued

Appendix		Page
A	Abbreviations Used in Engineering Geology	A-1
B	Geologic Drawing Drafting Standards and Symbols	B-1
	Explanation Drawings	B-1
	Overlays	B-1
	Lettering Sizes and Line Weights	B-3
	Standard Geologic Map Symbols	B-4
C	Geophysical Services and Geophysical Equipment Capabilities	C-1
	Borehole Geophysical Logging	C-1
	Equipment Used or Furnished by the Geophysics Section .	C-2
	Table C-1 - Borehole Geophysical Logs Available from the E&R Center	C-7
D	Duties of the Responsible Geologist	D-1
E	Protective Equipment and Visits to Construction Sites . . .	E-1
F	ACER Memorandum No. 31 - Requirements for Records of Geologic and Subsurface Investigations and for Records of Construction Materials and Foundation Materials Test Data to be Furnished to Prospective Bidders	F-1

CONTENTS - Continued

LIST OF FIGURES AND DRAWINGS

Figure or Drawing		Page
X-D-4244	Geology - Flow Chart of Events for Advertised Construction Contracts . . . . . Facing	3-2
1	Uniform Shear	5-13
2	Zoned Shear	5-14
3	Zoned Shear	5-14
4	Uniform Shear	5-14
5	Uniform Shear (Composite)	5-15
6	Signature blocks for Denver engineering drawings with geology prepared by the Division of Geology, E&R Center	10-4
7	Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by the Division of Geology, E&R Center	10-4
8	Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by regional, project, or field offices	10-5
9	Signature blocks for geology drawings prepared by the E&R Center	10-5
10	Signature blocks for geology drawings prepared by field offices	10-6
4103-D-574	Unified Soil Classification Chart	11-35
B-1	Identification of Overlays	B-2
B-2	Standard Lettering Sizes and Line Weights for Geologic Drawings	B-3
X-D-4247	Examples of Drill Hole Symbols for Geologic Cross Sections	B-5
X-D-4248	Standard Geologic Symbols Used for Geologic Sections and Columnar Sections	B-6
X-D-4249	Standard Geologic Map Symbols for Geologic Drawings . . . . . Facing	B-6

LIST OF TABLES

Table		
5-1	Igneous and metamorphic rock textures	5-4
5-2	Terminology for sedimentary and volcanic rocks and particles (after Wentworth)	5-5
5-3	Terminology for bedding, foliation, schistosity, and banding	5-6
5-4	Relationship of RQD and rock quality	5-12
5-5	Terminology for discontinuity spacing	5-13
11-1	Examples of Unified Soils Classification System as a secondary identification	11-13
C-1	Borehole geophysical logs available from the Engineering and Research Center	C-7

[redacted]

DCII

SECTION 1
BASIC CONCEPTS FOR ENGINEERING GEOLOGY PROGRAMS

This section outlines briefly the Bureau's fundamental concepts of engineering geology programs. The first subsection provides a definition of engineering geology. The second states the objectives of an engineering geology program and presents the stages the program should evolve through to ensure that proper and accurate geologic data are collected. The third subsection defines the basic sets of physical parameters for engineering geology.

Definition of Engineering Geology

The definition of engineering geology paraphrased from Glossary of Geology, Second Edition, 1980, is as follows:

> The application of geology to engineering practice, especially civil engineering. It includes the application of geologic data, techniques, and principles to the study of naturally occurring bedrock and soil materials, or ground water and environmentally related issues for the purpose of assuring that geologic factors affecting the location, planning, design, construction, operation, and maintenance of engineering structures, and the engineering aspects of development of ground-water resources, are properly recognized and adequately interpreted, utilized, and presented for use in engineering practice.

The Engineering Geology Program

Objectives of an Engineering Geology Program

The objectives of an engineering geology program are to identify adequately all of the relevant geologic considerations and to address them to the extent necessary to provide a professional engineering geology report.

All of the many varied and diverse engineering geology issues associated with a program can be assigned to one or more of the following groups of considerations:

1. Engineering considerations
2. Geologic hazards considerations
3. Environmental considerations
4. Economic considerations
5. Organizational and operational considerations

Most issues to be addressed fall into engineering, geologic hazards, or environmental considerations, and the great percentage of these must be resolved by a thorough knowledge of the physical aspects of engineering geology. Economic, organizational, and operational considerations, while not always included in technical reports, must be evaluated and resolved with a recognition of institutional structures and economic, political, and social standards. These nonphysical aspects of a program are the social aspects of engineering geology.

Classes of Engineering Geology Programs for Engineering Projects

1. Research
2. Planning (reconnaissance through feasibility studies)
3. Design for specifications
4. Construction
5. Operation and maintenance (including Safety of Dams and SEED programs)

Operational Phases of An Engineering Geology Program

The geologic investigation or study is dependent upon many situations. Before starting any investigation, it is important to understand fully the purpose of the investigation and the concepts and implications of the planned features. Aspects to be considered include the size and kind of feature; the physical environment, which included the location with respect to the public; geologic hazard potential; design requirements; cost; and political, public,

physical, and legal issues and concerns. Each investigation should be conducted in at least three phases. Phasing of a program encourages better definition and ranking of all issues and focusing of activities. That is, the program proceeds from the general to the specific. The three phases are:

1. Preliminary
2. Advanced
3. Final

Stages of Each Operational Phase

It is important to identify the geologic issues requiring resolution and the data needed to solve those issues. Each operational phase should evolve through the stages addressed below to ensure proper and accurate resolution of all geologic considerations.

1. Delineation and comprehension of site geology
2. Identification of engineering geology issues and their criticality
3. Collection of data (existing and new)
4. Collation, analysis, and interpretation of data
5. Reevaluation and solution issues
6. Preparation of findings

Basic Sets of Physical Parameters for Engineering Geology

Classification of Earth Materials

For engineering geology purposes, the solid material of the earth's crust is divided into the following major classifications:

1. Bedrock
2. Surficial deposits
3. Topsoil

Physical Characteristics of Earth Materials

Geologic descriptions of the physical characteristics of bedrock, surficial deposits, and topsoil can be grouped as follows:

1. Genetic (granite, schist, sandstone, alluvium, etc.)
2. Kinetic (folds, fractures, shears)
3. Alteration (decomposition, erosion, deposition, replacement)

Physical Elements of Engineering

It is incumbent on the engineering geologist to apply knowledge of geologic conditions to evaluate the geologic considerations for an engineering project. The basic physical elements of engineering geology which need to be identified and addressed during data collection and the evaluation of an issue are provided below. A more complete listing of these elements and the individual engineering geology issues is provided in section 7.

1. Geomechanical element (strength, discontinuities, and loads; includes mechanical, chemical, and climatic influences)

    a. Stability of earth materials
    b. Deformability of earth materials

2. Geologic fluids element (permeability, occurrence, storage, corrosivity, etc.)

    a. Ground-water occurrence and behavior
    b. Other fluid occurrence and behavior

3. Geochemical and geothermal element
4. Geologic hazards element
5. Environmental element

The addressing of an element requires information on the intrinsic "engineering" and "engineering geology" properties of the material and the conditions to which the material has been, is being, or will be subjected. Examples of some intrinsic properties of earth materials are: deformation modulus, unconfined compressive strength, permeability, storativity, and solubility. Stress, fluid pressure, chemical saturation of fluids, and temperature are types of present or future conditions experienced by the earth material.

SECTION 2
DEFINITIONS OF BASIC GEOLOGIC TERMS

The Glossary of Geology, Second Edition, published by the American Geological Institute, 1980, is the Bureau of Reclamation standard for definitions of geologic words and terms. If an author prefers a modified or more precise definition for a particular discussion, the redefinition should be so stated in each document in which it appears.

Some definitions in the Glossary of Geology do not fully satisfy general Bureau usage and will be replaced permanently by Bureau definitions. Some of these are given below:

Bedrock. - A general term that includes any of the generally lithified or crystalline earth materials that make up the earth's crust and are exposed at the earth's surface as outcrops or covered by surficial deposits.

Surficial deposits. - The relatively younger earth materials occurring at or near the earth's surface overlying bedrock. They occur as two major classes: (1) transported, generally eroded, or resulting from mass wasting of bedrock materials by water, wind, ice, gravity, and by man's intervention, and (2) sedentary or residual deposits formed in situ as a result of weathering and chemical processes or by the accumulation of organic matter. They can be stratified (basin fill, alluvial, or fluvial deposits) or unstratified (landslides, talus, etc.) They may be indurated or cemented with silicates, oxides, or carbonates (caliche or hardpan).

Topsoil. - An identifiable layer of surficial deposits usually consisting of the darker colored organic-rich A soil horizon or uppermost portion of the soil profile.

Fracture (structural geology). - In the broad context, a term for any discontinuity in surficial deposits and bedrock, whether or not it causes displacement, due to mechanical failure by stress and therefore includes cracks, joints, and shears. As used in engineering geology, fracture is restricted to breaks or discontinuities which do not exhibit shearing displacement and includes joints (systematic fractures), fractures (random fractures), and fissures (tensional fractures).

Shear. - A deformation resulting from stresses that cause contiguous parts of a body or rock mass to slide relatively to each other in a direction parallel to their plane of contact. A structure or discontinuity where differential movement has taken place along a surface or zones of failure by shear; characterized by slickensides, gouge fracturing, or any combination of these, but where direction and amount of displacement and continuity are generally not known. Usually displacement cannot be measured due to the absence of recognizable stratigraphic markers but may be inferred when drag is visible.

Fault. - A geologic structure or discontinuity with the physical characteristics of a shear, such as slickensides, fracturing, and gouge, and with measurable thickness, attitude, and continuity. It can also be defined as a "shear" which has been correlated between observations or occurs over a significant portion of a given site or foundation area.

Shear zone. - A shear zone may consist of gouge, breccia, or many related shears together with fractured and crushed rock, or any combination of these materials where displacement and continuity are generally not known.

Fault zone. - A fault that is expressed in relative terms of width. A fault zone may consist of fault gouge, fault breccia, or many related faults together with fractured and crushed rock, or any combination of any of these. A fault zone may be hundreds of meters or thousands of feet wide. In common usage, many well-known fault zones are simply referred to as faults.

SECTION 3

MILESTONE GEOLOGIC DOCUMENTS FOR BUREAU OF RECLAMATION DESIGNS AND SPECIFICATIONS OF THE ASSISTANT COMMISSIONER - ENGINEERING AND RESEARCH

The following milestone documents shall be authored by, or reviewed and approved by, the Responsible Geologist in the Division of Geology for each ACER specifications. The preparation of these documents will ensure the recording of geologic conditions and of geologic considerations and will permit a review of the geologic issues and their impacts and the data and conclusions presented to designers and engineers to design and construct Bureau facilities. The submittal dates for these documents are shown on drawing No. X-D-4244. These documents are:

Engineering Geology Review Memorandum

This memorandum shall be written by the Responsible Geologist in coordination with E&R Center engineers and in consultation with regional and/or project personnel. The memorandum should summarize geologic knowledge of the site, geologic conditions of major concern, such as open joints, bedding plane shears, and low density soils, discuss identifiable engineering geology issues, and set forth a schedule of activities which addresses the resolution of those issues and the preparation of geologic reports. Inclusion of drawings, sketch-drawings, tables, and photographs, if taken, is encouraged.

A draft of the memorandum shall be prepared by the Responsible Geologist prior to inspection of the site by the Design or Project Team. The final memorandum, including the proposed investigation program with schedules will be submitted by the Responsible Geologist within 1 month after the site visit by the team. The site visit will take place within 3 months of when the job is scheduled (BEGIN). The memorandum will be addressed to the appropriate Design branch(es), through the Geology Branch Chief and Chief, Division of Geology. Distribution copies shall be prepared for the Regional Director, Project Construction Engineer, and appropriate E&R Center branches.

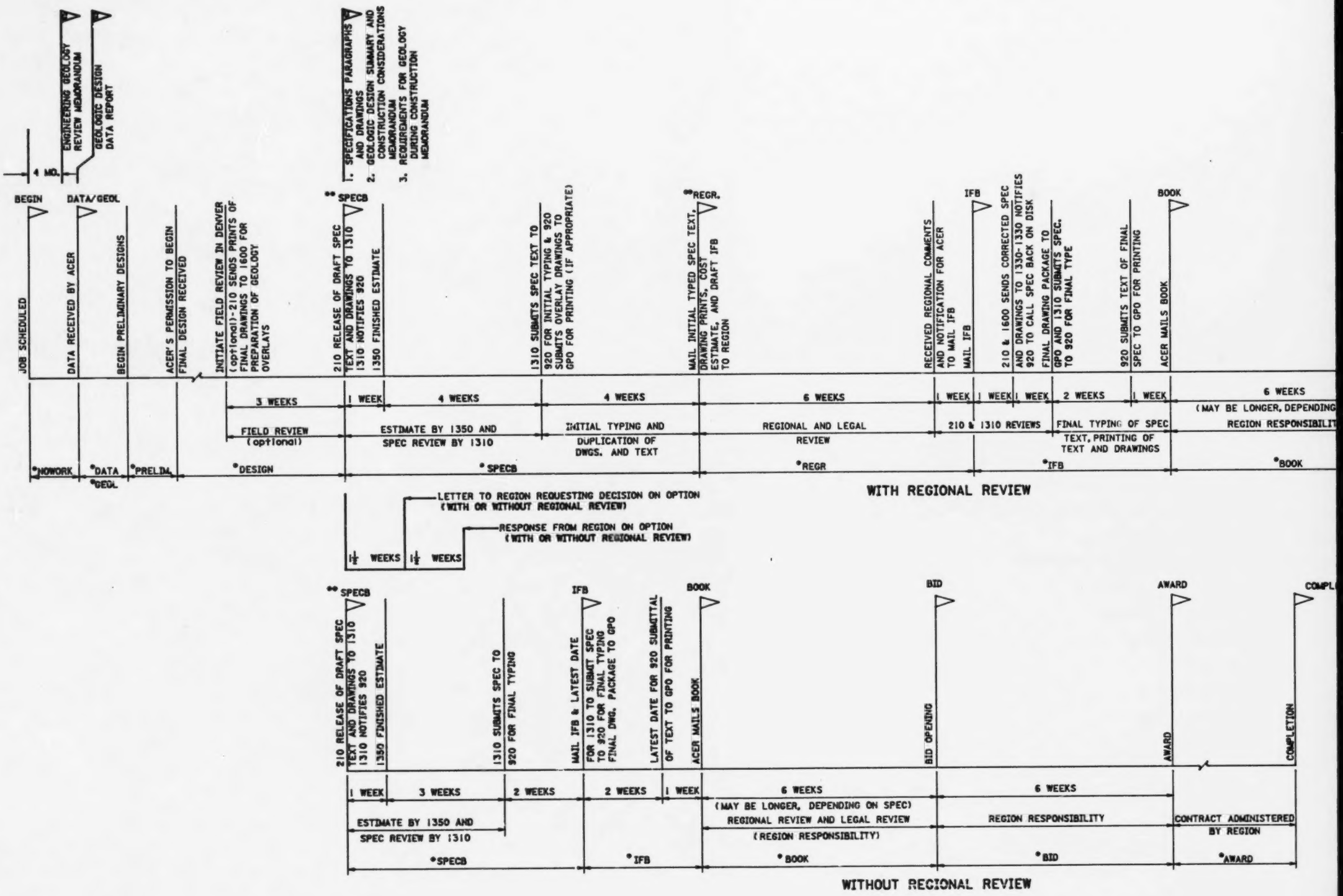
The Engineering Geology Review Memorandum should be prepared in the orderly sequence listed below:

1. A draft memorandum should be prepared and available for the Design or Project Team prior to the site inspection. The memorandum format should include the sections outlined below:

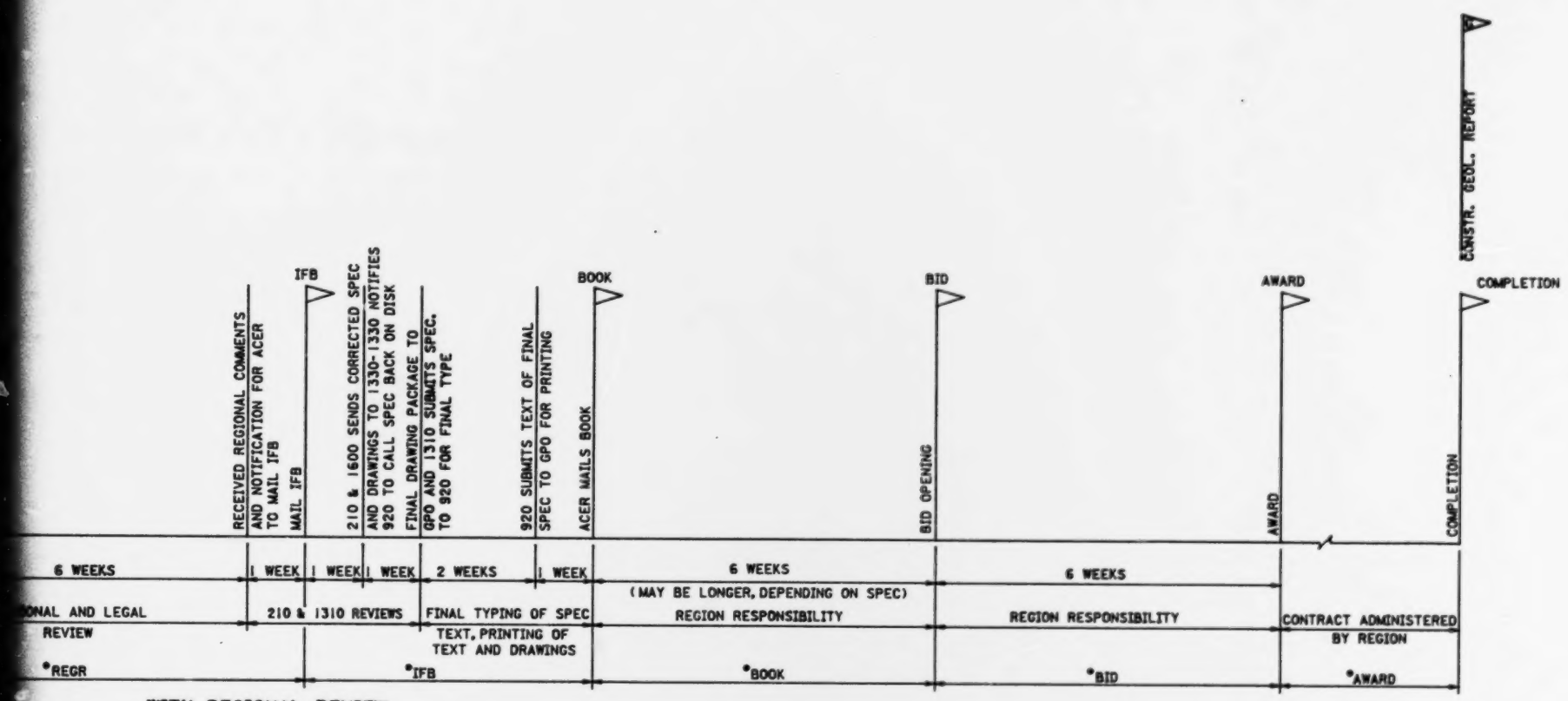
   a. Introduction
   b. Regional Geology
   c. Seismicity
   d. Geologic Investigations
   e. Site Geology
   f. Reservoir Geology (if appropriate)
   g. Geologic Design and Construction Considerations
   h. Construction Materials
   i. Investigations and Schedule Requirements (prepared after site inspection)

2. The Project Team (for dams) or Design Team (for other structures) meeting will be held at the site to determine investigation requirements within 3 months after construction funding is available. The Principal Designer(s), Responsible Geologist, materials specialist(s), regional and/or project personnel, and other interested parties should outline all geologic and related investigations requirements. Personnel responsible for providing drilling functions should also be present. Time schedules for completion of the investigations will be developed and agreed upon. Less participation will be required for smaller or less complex structures.

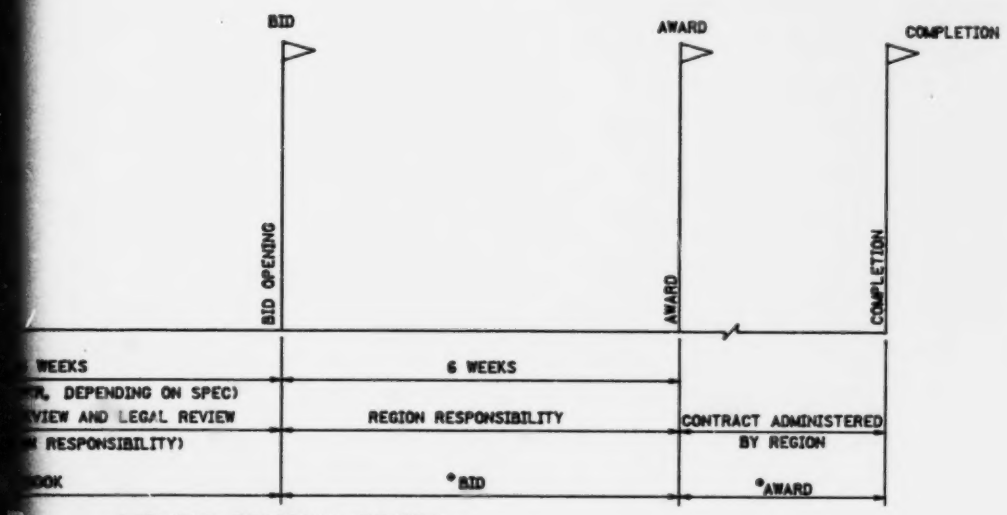
Part of the team's responsibility will include the evaluation of the time constraints and scheduled completion dates for geologic design data collection, and the costs of the geologic investigations. Duplication of subsurface exploration and sampling may result if objectives of the investigations are not "scoped."


4 MO.
ENGINEERING GEOLOGY REVIEW MEMORANDUM
GEOLOGIC DESIGN DATA REPORT
1. SPECIFICATIONS PARAGRAPHS AND DRAWINGS
2. GEOLOGIC DESIGN SUMMARY AND CONSTRUCTION CONSIDERATIONS MEMORANDUM
3. REQUIREMENTS FOR GEOLOGY DURING CONSTRUCTION MEMORANDUM
BEGIN
DATA/GEOL
**SPECB
**REGR.
IFB
BOOK
JOB SCHEDULED
DATA RECEIVED BY ACER
BEGIN PRELIMINARY DESIGNS
ACER'S PERMISSION TO BEGIN FINAL DESIGN RECEIVED
INITIATE FIELD REVIEW IN DENVER (optional)-210 SENDS PRINTS OF FINAL DRAWINGS TO 1600 FOR PREPARATION OF GEOLOGY OVERLAYS
210 RELEASE OF DRAFT SPEC TEXT AND DRAWINGS TO 1310
1310 NOTIFIES 920
1350 FINISHED ESTIMATE
1310 SUBMITS SPEC TEXT TO 920 FOR INITIAL TYPING & 920 SUBMITS OVERLAY DRAWINGS TO GPO FOR PRINTING (IF APPROPRIATE)
MAIL INITIAL TYPED SPEC TEXT, DRAWING PRINTS, COST ESTIMATE, AND DRAFT IFB TO REGION
RECEIVED REGIONAL COMMENTS AND NOTIFICATION FOR ACER TO MAIL IFB
MAIL IFB
210 & 1600 SENDS CORRECTED SPEC AND DRAWINGS TO 1330-1330 NOTIFIES 920 TO CALL SPEC BACK ON DISK
FINAL DRAWING PACKAGE TO GPO AND 1310 SUBMITS SPEC. TO 920 FOR FINAL TYPE
920 SUBMITS TEXT OF FINAL SPEC TO GPO FOR PRINTING
ACER MAILS BOOK
3 WEEKS
1 WEEK
4 WEEKS
4 WEEKS
6 WEEKS
1 WEEK
1 WEEK
1 WEEK
2 WEEKS
1 WEEK
6 WEEKS
(MAY BE LONGER, DEPENDING
REGION RESPONSIBILIT
FIELD REVIEW (optional)
ESTIMATE BY 1350 AND SPEC REVIEW BY 1310
INITIAL TYPING AND DUPLICATION OF DWGS. AND TEXT
REGIONAL AND LEGAL REVIEW
210 & 1310 REVIEWS
FINAL TYPING OF SPEC TEXT, PRINTING OF TEXT AND DRAWINGS
*NOWORK
*DATA
*GEOL
*PRELIM
*DESIGN
*SPECB
*REGR
*IFB
*BOOK
WITH REGIONAL REVIEW
LETTER TO REGION REQUESTING DECISION ON OPTION (WITH OR WITHOUT REGIONAL REVIEW)
RESPONSE FROM REGION ON OPTION (WITH OR WITHOUT REGIONAL REVIEW)
1½ WEEKS
1½ WEEKS
**SPECB
210 RELEASE OF DRAFT SPEC TEXT AND DRAWINGS TO 1310
1310 NOTIFIES 920
1350 FINISHED ESTIMATE
1310 SUBMITS SPEC TO 920 FOR FINAL TYPING
IFB
MAIL IFB & LATEST DATE FOR 1310 TO SUBMIT SPEC TO 920 FOR FINAL TYPING FINAL DWG. PACKAGE TO GPO
LATEST DATE FOR 920 SUBMITTAL OF TEXT TO GPO FOR PRINTING
BOOK
ACER MAILS BOOK
BID
BID OPENING
AWARD
AWARD
COMPL
COMPLETION
1 WEEK
3 WEEKS
2 WEEKS
2 WEEKS
1 WEEK
6 WEEKS
(MAY BE LONGER, DEPENDING ON SPEC)
6 WEEKS
6 WEEKS
ESTIMATE BY 1350 AND SPEC REVIEW BY 1310
REGIONAL REVIEW AND LEGAL REVIEW (REGION RESPONSIBILITY)
REGION RESPONSIBILITY
CONTRACT ADMINISTERED BY REGION
*SPECB
*IFB
*BOOK
*BID
*AWARD
WITHOUT REGIONAL REVIEW

BEST DOCUMENT AVAILABLE



WITH REGIONAL REVIEW



WITHOUT REGIONAL REVIEW

NOTES

*Stage notation as used in Denver office spec schedule.
NOWORK—Job is scheduled but design data hasn't been received.
DATA---Design data has been submitted.
GEOL---Geologic design data has been received
PRELIM--Preliminary design is underway.
DESIGN--Final design is underway.
SPECB--Specification has been released to Code 1310
IFB-----Invitation for bids has been mailed.
BOOK----Specification book has been mailed to prospective bidders.
BID-----Bid opening has taken place.
AWARD---Contract has been awarded.

**Flag dates of primary concern to the Assistant Commissioner- Engineering and Research.

Times are average times and may vary depending on workload and complexity.
This flow chart does not apply to negotiated or 8A type contracts.

GEOLOGY
FLOW CHART OF EVENTS AND ACTIVITIES FOR ADVERTISED CONSTRUCTION CONTRACTS

BUREAU OF RECLAMATION
DENVER, COLORADO
SEPT. 1981

X-D-4244

10A BEST DOCUMENT AVAILABLE

3. Section i., which will be added to the original draft memorandum, will be prepared by the team participants during the site inspection.

4. The completed draft memorandum (sections a. through i.) will be reviewed by all E&R Center organizational divisions that may have input into the program, and their comments and concerns will be added to the memorandum before it is finalized.

5. The final Engineering Geology Review Memorandum will be prepared in the Division of Geology and disseminated by the Assistant Commissioner - Engineering and Research to all personnel concerned. This memorandum will be used as the guide and schedule for gathering geologic design data.

The Responsible Geologist and Project or Regional Geologists will coordinate the investigations programs in their related offices. Subsequent changes to the investigation, if required, will be coordinated and agreed upon so that data acquisition and the Geologic Design Data Report are completed by the GEOLOGY (DATA-G) date or a rescheduled GEOLOGY date.

Geologic Design Data Report

The report shall be prepared in the Project or Regional Office, shall be submitted in accordance with Reclamation Instructions 133.4.1, and is due in the E&R Center Division of Geology office on or before the GEOLOGY or design DATA date. Preparation of the report, submittal dates, and review procedures are discussed in section 9. The Responsible Geologist shall review the report to determine whether it is complete, satisfies the data requirements set forth in Reclamation Instructions and the Engineering Geology Review Memorandum, specifically addresses design requirements, and that it is technically adequate for initiation of design. The report shall then be approved by the Responsible Geologist and the appropriate Geology Branch Chief. Chief, Division of Geology and the Chief Design Engineer concurrence is required. This report shall address regional and site

geology, reservoir geology (if applicable), and geologic considerations. When required, the report shall specify the need for additional geologic studies and geologic design data and the due dates of supplements to the report which address this later work. The Responsible Geologist will review the data and prepare a written response to the region within 10 working days after receipt of the report or a supplement for small structures and within 20 working days for large structures, as categorized in section 10.

Specifications Paragraphs and Drawings

These shall be written and prepared by the Responsible Geologist and reviewed by the Regional or Project Geologist, either formally during the Regional Review and/or informally if no Regional Review is scheduled. Signatory approval of the paragraphs and drawings will follow the instructions contained in section 10.

Records of Geologic and Subsurface Investigations and Records of Construction Materials and Foundation Materials Test Data accumulated during the investigation and design process, which are determined to be of potential value to the bidders, shall be made by the Responsible Geologist and Principal Designer with input and concurrence from the line organization (see appendix F).

Geologic Design Summary and Construction Considerations Memorandum

This memorandum shall be written by the Responsible Geologist and be in final form at the SPECB date. A draft of this memorandum is required 1 month prior to SPECB date for use during the field review of the specifications.

The memorandum shall be in two parts. The first, titled "Geology for Design Summary," the second, "Geology for Construction Considerations." The first part will be incorporated by the designers into the "Design Summary" for the

feature while the second part will be included in the printed "Construction Considerations" for a given specifications.

"Geology for Design Summary" shall summarize the sources of the geologic data utilized in the design process and present or reference the final geologic considerations used for design and construction of the feature(s).

"Geology for Construction Considerations" shall discuss the geologic implications for construction and set forth the geologic requirements during construction, such as necessary mapping, notifications, and documentation.

Requirements for Geology During Construction Memorandum

This memorandum shall be written by the Responsible Geologist for signature by the Chief, Division of Construction and sent to the Project Construction Engineer. This memorandum is required only if there is to be a resident site geologist or geologists who are to be on the staff of the Project Construction Engineer or assigned to his office. When required, the memorandum is due no later than the SPECB date. The memorandum should contain a discussion of the anticipated staffing needs for geologists at the site with only a brief reference to the major geologic requirements. Detailed discussion of the geologic requirements during construction should appear in the "Geology for Design Summary and Construction Considerations Memorandum," appropriate portions of which will be incorporated into the printed "Construction Considerations" for the specifications.

Construction Geology Report

This report shall be written by Project or Regional Geologists in accordance with Reclamation Instructions, Part 171.6. The Responsible Geologist shall review, approve, and prepare a written response to the region within 20 working days after receipt of the report.

SECTION 4
COLLECTION OF GEOLOGIC INFORMATION

This section provides general guidelines for the collection, completeness, and description of geologic information. Geologists should apply these guidelines, using good judgment, to elaborate upon them as required by the particular geologic setting and engineering requirements. Also, the geologist must continually be aware of the design concepts and engineering geology issues for which this information is being collected and used (see sections 7 and 9). These guidelines are not intended to be all inclusive as to requirements or topics for each site investigation but, if used appropriately, they should provide adequate guidance to formulate and initiate a data acquisition program to apply the data and analyses to design and construction considerations. Minimum foundation data and investigation requirements for many structures are defined in Reclamation Instructions, Series 130, Part 133. These guidelines are as follows:

1. Compile, summarize, and document Bureau and non-Bureau geologic activities in the project area with special attention being paid to the sequence and results of studies and explorations.

2. Prepare geologic drawing(s) and map(s) showing location of explorations. Locations of all existing explorations should be indicated by coordinates and/or stationing and, when possible, by using the permanent survey control system for the facility. Develop surface geology maps, a stratigraphic column, geologic cross sections at appropriate scales to portray surface and subsurface conditions, and special purpose drawings for sites with complex geology or design. See Section 6, Interpretation and Presentation of Geologic Design Data.

3. Prepare narrative description of surficial deposits, including topsoil, specifying geologic properties, especially those which may affect design or construction. These may include but are not restricted to such characteristics as swelling minerals, low-density materials, presence

of gypsum and other sulfates, caliche, dispersive soils, loose deposits subject to liquefaction or consolidation, permeable materials, erodibility, and oversize (see Earth Manual 1/). The following checklist may be useful as a general, though not necessarily complete, guide for descriptions. Instructions for logging and describing soils in geologic explorations are provided in section 11.

a. Distribution, occurrence, and relative age; relationship with present topography; and correlation with features such as terraces, dunes, undrained depressions, and anomalous protuberances.

b. Geologic identification and general classification of materials. Soils should be classified according to the Unified Soil Classification System.

c. Dimensional characteristics (e.g., thickness, variations in thickness, shape).

d. Physical characteristics (e.g., color, grain size, consistency or compactness, cohesion, cementation, moisture content, mineral deposits, content of expansive or dispersive minerals, alteration, fissures, or fractures). Use descriptors established for the Unified Soils Classification System.

e. Distribution, extent, and significant effects of altered zones.

f. Response to natural surface and near-surface processes (e.g., raveling, gullying, subsidence, expansion, creep, slope washing, slumping, and sliding).

4. Prepare descriptions of bedrock with attention being paid to both geologic properties and engineering geologic properties such as strength,

---

1/ Earth Manual, Second Edition, Bureau of Reclamation, 1974.

swelling minerals, presence of gypsum and other sulfates, depths of weathering, joints, faults, and other planes of weakness. The following checklist may be useful as a general, though not necessarily complete, guide for descriptions (see section 5).

a. Bedrock units. - Traceable lithologic units of similar physical properties should be identified and characterized.

- Identification as to rock type (e.g., granite, silty sandstone, mica schist).

- Relative age and, where possible, correlation with named formations (e.g., Idaho Springs Formation, Navajo Sandstone).

- Distribution and dimensional features (e.g., thickness, outcrop breadth, areal extent).

- Physical characteristics (e.g., color; texture; grain size; nature of stratification, bedding, foliation, or schistosity; hardness; and chemical features such as calcareous or siliceous cementation; concretions, mineral deposits, alteration other than weathering).

b. Distribution and extent of weathering and alteration. - Weathering should be divided into categories that reflect definable physical changes in the rock mass due to weathering. Significant differences should be identified and weathering profiles developed.

- Response to natural surface and near-surface processes (e.g., raveling, gullying, mass movement).

c. Structural features. - Bedding planes, cleavage, joints, contacts, shear and fault zones, folds, zones of contortion or crushing, etc.

- Occurrence and distribution.

- Dimensional characteristics (e.g., width, spacing, continuity).

- Orientation and changes in attitude.

- Relative ages (where pertinent).

- Special effects upon the bedrock (describe the conditions of planar surfaces, such as openness, roughness, a waviness of surfaces, striations, mineralization, alteration, and infilling or healing).

- Statistical evaluations of distribution, orientation, and special effects.

- Specific features of shears or faults [e.g., description of composition of the fault, zones of gouge and breccia, nature of offsets, attitude of slickensides, relative age of movement(s)].

5. Include laboratory determinations of engineering properties of surficial deposits and bedrock.

6. Provide black and white photographs of representative or particular geologic conditions, drill hole core, samples, and test pits and color photographs or transparencies if appropriate or desired.

7. Summarize data from remote sensing and geophysical surveys (seismic, resistivity, etc.), if performed and correlate with other geologic information.

8. Describe investigations of ground-water conditions, noting water levels or piezometric surfaces and their seasonal fluctuation, occurrence of unconfined and confined aquifers, potential seepage, water-producing capabilities, chemistry, and ground subsidence. The following checklist may be useful as a general, though not necessarily complete, guide for descriptions:

a. Distribution, occurrence, and relationship to topography (e.g., streams, ponds, swamps, springs, seeps, subsurface basins).

b. Existence of confined or unconfined aquifers and relationship to geologic features (e.g., impervious and pervious strata, fractures, faults).

c. Recharge sources and permanence.

d. Variations in amounts of water and dates the measurements were recorded (e.g., intermittent springs and seeps).

e. Evidence for earlier occurrence of water at localities now dry (e.g., vegetation, mineral leaching or deposition, relict karst, historic records).

f. The effect of water on the properties of the in-place materials including field and laboratory observations.

9. Prepare accurate and complete logs of explorations using terminology consistent with the narrative (see section 5). Give consideration to appropriate indexes (e.g., RQD, PR).

10. Run appropriate borehole geophysical logs in drill holes and other appropriate geophysical surveys to delineate subsurface conditions.

11. Evaluate landslides, avalanches, rockfalls, erosion, floods, etc. The following checklist may be useful as a general, though not necessarily complete, guide of descriptions:

a. Features representing accelerated erosion (e.g., cliff reentrants, badlands, advancing gully heads).

b. Features indicating subsidence, settlement, or creep (e.g., fissures, bulges, scarplets, displaced or tilted reference features, historic records, and measurements).

c. Slump and slide masses in bedrock and/or surficial deposits, their distribution, geometric characteristics, correlation with topographic and geologic features, age, and rates of movements.

12. Describe investigations undertaken to evaluate the age and recurrence of faulting in the project vicinity, especially if suspected to be late Pleistocene or Holocene age, to assist in the determination of design earthquakes for critical structures.

13. Describe past, present, and possible future petroleum, water, and mineral extraction operations in the vicinity.

14. Describe investigations undertaken to ascertain geologic conditions which may affect construction methods such as boulders, marshes, drilling conditions, stability of grout or footing holes, ground temperature, and gases.

15. Map land uses, particularly along linear features such as canals, transmission lines, distribution systems, and highways.

16. Provide corrosion surveys for all proposed conveyance facilities to determine whether special mitigation measures will be required. Corrosion surveys shall be provided for all Bureau distribution systems, including pipelines, aqueducts, discharge lines, and siphons. The Responsible Geologist shall notify the Geophysics Section, code D-1631, as soon as the conveyance structure is scheduled and provide design information such as depth of cover, size and length of pipeline, and drawings to code D-1631 as soon as they are available.

The Geophysics Section is responsible for the formulation of the corrosion survey and will transmit a memorandum requesting the survey to the appropriate field office. The survey will include:

a. Electrical resistivity soundings along the pipeline alinement to determine the degree of corrosion protection required.

b. A stray current survey to determine the amount and type of cathodic protection for existing pipelines (within 200 feet) and wells (within one-fourth mile) along the alinement.

c. An evaluation of performance history of buried metalwork in the area.

d. Information as to the location and availability of permanent electrical power for a possible cathodic protection system.

The completed survey, along with a location map(s), shall be transmitted to the E&R Center, attention code D-1631. The Geophysics Section will then process and interpret the resistivity data, prepare and maintain a report in their files, and forward the results along with the other material to Materials Science Section, code D-1521. The Materials Science Section will make recommendations for the corrosion protection required and transmit them to the Mechanical Branch, code D-250, and the Water Conveyance Branch, code D-270, for inclusion in the specifications.

The field data sheets will be checked, prepared in final form, and furnished to the appropriate Geology Branch along with any location map(s) for inclusion in the specifications.

SECTION 5

TERMINOLOGY FOR THE DESCRIPTION OF PHYSICAL PROPERTIES OF EARTH MATERIALS

Basic definitions for some geologic terms were addressed in section 2. This section provides definitions and standardized descriptors for physical properties of engineering significance. The need for some standardization of geologic terminology has long been recognized because it is important that engineers, as well as geologists, be able to draw the same conclusions from any log of exploration or report, regardless of which geologist prepared it. Therefore, the following standardized descriptors for physical properties are provided to ensure that geologic data are recorded uniformly, consistently, and accurately. These descriptors will assist new geologists in adapting to Bureau terminology and procedures, will minimize revisions and editing, will permit better analysis of the data for design and construction considerations and specifications preparation, and reduce claims during construction due to inconsistent terminology and descriptions. Specific adaptations or refinements may be established to meet project or design requirements, or site-specific geologic complexity. If these standardized descriptors are refined or modified, they must be redefined in the applicable geologic reports and in appropriate geologic notes on drawings.

General

Surficial Deposits

Surficial deposits (slopewash, alluvium, colluvium, residual soil, etc.) are normally described using the Unified Soils Classification System. For drainage and land classification work, the USDA Agricultural Soils Classification System is used. Where the surficial materials are very shallow or will not be used in or influence design or construction (slopewash, drill pad, or road fill), or where rockbitted, they may be given a general description in logs of exploration. Section 11 provides requirements for the logging of soils in

geologic explorations. The general descriptions in the narrative should include the following:

1. Typical name
2. Classification descriptors - additional descriptors (particle sizes, dilatancy strengths, consistency, compactness, etc.)
3. Moisture
4. Color
5. Reaction to HCl
6. Cementation
7. Permeability

If in-place conditions are not observable, describe as many of the above items that can be determined from surface observations, road cuts, cuttings, drill water color, drilling characteristics, correlation to surface exposures, etc. Uniformity of descriptions for logs of exploration and reports is very desirable; and descriptors for compactness, consistency, structure, etc., should conform to those of the guidelines established for the Unified Soil Classification System (see section 11).

Bedrock

Descriptions of bedrock include the formation name and age, if known or possible to determine, and a description of the bedrock's generalized lithologic and physical features. A general outline is provided below:

1. Rock name. - A simple descriptive name sufficient to provide others with possible engineering properties of the rock type.

2. Composition/grain sizes/texture. - Brief lithologic description; describe grain size or sizes; textural adjectives such as vesicular, porphyritic, (do not use academic or sophisticated terms such as hypidomorphis, subidioblastic, etc.); structural adjectives such as bedding, foliation, schistosity, or banding (include inclination or dip). These features can be used for correlations and interpretations.

3. Color. - Provide color of fresh and weathered surfaces.

4. Hardness. - Use appropriate descriptors presented in this section.

5. Weathering. - Use appropriate descriptors presented in this section.

6. Discontinuities. - Description of cleavage and/or bedding planes, joints and fractures, including their attitude, spacing, continuity, openness, surfaces, and filling. Descriptors for some of these properties are provided in this section; others will be developed and included at a later date.

Descriptors for Physical Characteristics of Bedrock

Uniformity of definitions and descriptors is important to maintain continuity of logs and reports from a project with multiple drilling seasons, different loggers and mappers, and as a reminder to the geologist to record all significant parameters when logging or mapping. This section provides descriptors for characteristics that should be described or noted in the logs of exploration, in narratives of reports, and on preconstruction geologic maps and cross sections, as well as construction or "as built" drawings. The descriptors used should be defined and included in a legend for all data submitted for design or record of construction.

Lithology

Provide a general description, including texture and general mineral composition (macrodescription of mineral components). Detailed mineral composition is generally not necessary or desirable unless it is useful in correlating units or indicating physical properties pertinent to engineering geology. Hand specimens or core samples may be submitted to the E&R Center Petrology Laboratory for identification if desired. Use standard adjectives such as sandy, silty, calcareous, etc. Note inclusions, concretions, nodules, cementation, etc. An excellent publication for the field classification of

rocks is available from the Colorado School of Mines, Golden, Colorado. Reprints of the Quarterly of the School of Mines, volume 50, No. 1, January 1955, "Classification of Rocks," may be obtained for a nominal charge.

1. Texture and grain size. -

a. Sedimentary and volcanic rocks. - Terminology for particle size and their lithified products forming sedimentary and volcanic rocks are provided in table 5-2. The size limits are after Wentworth; they do not correspond to the Unified Soils Classification System but are common usage for description of rock units and petrology classification in geology literature and are used by the Bureau Petrology Laboratory.

b. Igneous and metamorphic rocks. - Table 5-1 (after Wahlstrom) should be used for description of textures of igneous and metamorphic rocks.

Table 5-1. - Igneous and metamorphic rock textures

Texture	Average grain diameter
Very coarse grained (pegmatitic)	>30 mm
Coarse grained	10-30 mm
Medium grained	1-10 mm
Fine grained	0.1-1 mm
Aphanitic	<0.1 mm

2. Textural adjectives. - Use simple, standard textural adjectives such as porphyritic, vesicular, pegmatitic, granular, grains well developed, etc. Use of sophisticated terms such as holohyaline, hypidiomorphic granular, crystaloblastic, cataclastic, etc., should be avoided.

3. Bedding, foliation, schistosity, flow structure, and banding. - These features give the rock anisotropy of its physical properties. Continuity and spacing of these features can be large or discontinuous, and their

Table 5-2. - Terminology for sedimentary and volcanic rocks and particles (after Wentworth)

USCS (soils only) Particle size	Size in mm	Sedimentary (epiclastic) Rounded, subrounded, subangular: Particle or fragment	Sedimentary (epiclastic) Rounded, subrounded, subangular: Lithified product	Volcanic (pyroclastic): Fragment	Volcanic (pyroclastic): Lithified product
Boulder	300	Boulder	Boulder conglomerate	Block	Volcanic breccia
	256				
Cobble	75	Cobble	Cobble conglomerate	Bomb	Agglomerate
	64				
Coarse gravel	20	Pebble	Pebble conglomerate	32 mm Lapilli	Lapilli tuff
Fine gravel	4.75				
	4	Granule	Granule conglomerate		
Coarse sand	2	Very coarse sand	Sandstone (Very coarse, coarse, medium, fine, or very fine)	Coarse ash	Coarse tuff
	1	Coarse sand			
	0.5				
Medium sand	0.42	Medium sand			
	0.25			0.25 mm	
Fine sand	0.125	Fine sand			
	0.074	Very fine sand			
	0.0625				
Fines: Nonplastic Silt / Plastic Clay		Silt	Siltstone Shale	Fine ash	Fine tuff
	0.00391	Clay	Claystone Shale		

BEST DOCUMENT AVAILABLE

influence on the rock mass cannot always be tested in the laboratory. Descriptors in table 5-3 are recommended.

Table 5-3. - Terminology for bedding, foliation, schistosity, and banding

Bedding	Foliation, schistosity, banding	Thickness
Laminated	Very narrowly spaced	Less than 3/8 in (10 mm)
Very thinly bedded	Very closely spaced	3/8 to 2 in (10 to 50 mm)
Thinly bedded	Closely spaced	2 in to 1 ft (50 to 300 mm)
Medium bedded	Moderately spaced	1 to 3 ft (300 mm to 1 m)
Thickly bedded	Widely spaced	3 to 10 ft (1 to 3 m)
Very thickly bedded	Very widely spaced	Greater than 10 ft (3 m)

4. Contacts. - The nature of contacts between lithologic units should be described. In addition to a description of their planarity or irregularity, other descriptors are pertinent. Some of these are:

Gradational (sedimentary or metamorphic)
Unconformable (sedimentary)
Welded - contact between two lithologic units, one of which is igneous, that have not been disrupted tectonically
Concordant (igneous) - contact between an igneous intrusion and the country rock which parallels the foliation or bedding planes of the latter
Discordant (igneous)
Broken - contact not welded, cemented, or healed
Healed (by secondary process)
Sheared or faulted

Hardness - Strength

The behavior of the rock mass is, in part, influenced by rock strength, and hardness can be related to rock strength. Rock strength plays a dominant role in engineering design and construction, such as tunnel support requirements, allowable bearing pressures, and excavation methods and support; all,

often directly, depend on the rock strength. The large differences in hardness are important, not the subtle or slight differences. The hardness and strength of rock and the rock mass are functions of the individual rock type but also may be modified by weathering or alteration. Hardness and strength should be described for each geologic unit when they are functions of the rock type and also for alteration when there are various degrees of hardness due to different intensities of weathering or other chemical alteration. Hardness and strength are diffcult characteristics to express. It is important to note whether the core or rock fragments break around, along, or through grains, along or across discontinuities, bedding, schistosity, or foliation. The diameter of core or size of fragment will influence the geologist's description of strength, and the geologist should keep this in mind when correlating strengths. A 5- to 8-inch (130- to 200-mm) core length or rock fragment, if available, should be used for hardness determinations to preclude erroneously reporting local rather than average hardness, and to evaluate the tendency to break along incipient fractures, textural, or structural properties when struck with a hammer. To maintain consistency, each geologist should calibrate his standards with those of other geologists mapping or logging core at the project.

Each project will have different rock conditions; therefore, a hardness scale should be established early and used during the investigations. A range of compressive strengths can be devised for each of the hardness descriptors after a testing program is completed. "Pocket" penetrometers, Schmidt hammers, or point load tests for estimating engineering property indices also may be used in the field where design requirements warrant their use.

1. Extremely hard. - Specimen can only be chipped with repeated heavy hammer blows.

2. Very hard. - Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.

3. Hard. - Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.

4. Moderately hard. - Can be scratched with knife or sharp pick with light or moderate pressure. Core breaks with moderate hammer blow.

5. Medium. - Can be gouged 1/16 inch (2 mm) deep by knife or sharp pick with (moderate or heavy) pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.

6. Soft. - Can be gouged by knife or sharp pick with light knife pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.

7. Very soft. - Can be readily indented or gouged with fingernail or carved with a knife. Breaks with light manual pressure, smaller fragments with finger pressure.

Weathering

Weathering is the chemical or mechanical breakdown of a rock which can significantly affect the engineering properties of the rock and rock mass. The term "weathering" is used synonymously with "decomposition" as one of the agents of alteration. Increases in compressibility, decreases in shear and compressive strengths, and a decrease in erosion resistance are major engineering parameters that weathering can influence. It can drastically affect the strength of a rock and is generally indicated visually as changes in the color and texture of the body of the rock and/or color of fracture fillings and surfaces. Weathering should be reported by the following descriptors.

1. Decomposed. - Rock usually soil-like but with remnant rock features and structure preserved. Quartz may be present as stringers or dikes. Crumbles in fingers. Always classified as common excavation.

2. Intensely weathered. - Highly oxidized; Fe-Mg and feldspar minerals weakened and crumbly. In granitoid rocks, all feldspars are altered or kaolinized to some extent. Body of rock usually is completely discolored by weathering. Leaching of soluble minerals may be complete. Usually can be broken with moderate to heavy manual pressure or by a light hammer tap without reference to planes of weakness such as hairline fractures and veinlets. Always classified as common excavation.

3. Moderately weathered. - Oxidized, usually throughout; Fe-Mg minerals "rusty;" feldspars "cloudy," but not weak. Body of rock is discolored and slightly weakened by weathering. "Rust" stains and/or silt or clay coatings are common on all discontinuities. Soluble minerals may be partially leached. Rock has dull sound when struck with hammer. Depending on fracturing, this material is usually rock excavation except in naturally weak rock such as siltstone or shale.

4. Lightly weathered. - Partially oxidized; body of rock usually fresh. In granitoid rocks, some feldspar crystals are dull and discolored. Oxidation usually is limited to the surface of, or a short distance from, joints and fractures. Minor localized leaching of soluble minerals. Crystalline rocks ring with hammer blow. With few exceptions, classified as rock excavation.

5. Fresh. - Not oxidized; has no discoloration or stains on fracture surfaces. Almost always rock excavation except for naturally weak rock such as shales.

NOTE: Combination descriptors of weathering are permissible (i.e., intensely to moderately weathered) where equal distribution of both weathering characteristics are present over significant intervals or where characteristics present are "in between" the descriptor definitions. However, dual classification should not be used where significant identifiable zones can be delineated and described. When given as a range, only two adjacent ranges may be combined (i.e., decomposed to lightly weathered or moderately weathered to fresh are not acceptable).

Discontinuities

Discontinuities are present in all rock masses in the form of planes or surfaces of separation which include cleavage, bedding, fractures, joints, or zones of crushing or shearing. Because discontinuities control or significantly influence the behavior of the rock mass, they must be described in detail. Discontinuities to a large extent control the strength, deformation, and permeability of a rock mass. Each set of discontinuities, based on similar orientation, should be described separately. Properties to be addressed include spacing, thickness of infillings or width of fracture openings, presence of moisture on surfaces, continuity of joints, roughness and waviness, and alteration of surfaces.

1. Fracture density. - Fracture density is based on the spacing of all natural fracture in an exposure or core recovery lengths in boreholes excluding mechanical breaks and shear zones. These discontinuities always should be described in physical measurements, but descriptive terms relating to these measurements are convenient and aid in communicating characteristics of the rock mass for all investigations. Descriptors with different physical measurements can be established at the project if required, providing they are consistent in logs, maps, and narrative and are defined. An explanation of fracture density should be included in the narrative of the report and on the geologic note drawing. Standardized descriptors for fracture density apply to all exposures such as tunnel walls, dozer trenches, outcrops, or foundation cut slopes and inverts, as well as boreholes. Descriptors presented below are based on cores from boreholes where lengths are measured along the core axis. In exposures, the average smallest dimensions between fractures are recorded.

   a. Very intensely fractured. - Core recovered mostly as chips and fragments with a few scattered short core lengths.

   b. Intensely fractured. - Core recovered mostly in lengths less than 0.5 foot (150 mm) long. Lengths probably average from 0.1 to 0.3 foot (30 to 90 mm) with scattered fragmented intervals.

c. Moderately fractured. - Core recovered mostly in 0.5- to 1.5-foot (150- to 450-mm) lengths with most lengths about 1 foot (300 mm).

d. Lightly fractured. - Core recovered mostly in lengths from 1.5 to 3 feet (450 to 900 mm) with few scattered lengths less than 1.5 feet (900 mm) or greater than 3 feet (900 mm).

e. Very lightly fractured. - Core recovered mostly in lengths greater than 3 feet (900 mm).

NOTE: Combinations of fracture densities are permissible (e.g., very intensely to intensely fractured or moderately to lightly fractured) where equal distribution of both fracture density characteristics are present over a significant interval or exposure or where characteristics are "in between" the descriptor definitions.

It is usually helpful to provide a percentage of the types of discontinuities. A complete description for fracture density might read: Lightly fractured, recovered core in 1.5- to 4.7-ft (0.5- to 1.4-m) lengths, mostly 1.7-ft (520-mm) (25 percent bedding/75 percent joints).

2. Rock Quality Designation. - The RQD (after Deere) method of determining rock quality is a diagnostic description intended primarily for evaluating problems with tunnels or excavations in rock. RQD was developed for Nx-size core using the following criteria:

Sum the total length of core recovered in each run, but count only those pieces of core which are 4 inches (100 mm) in length or longer and which are "hard and sound." The length of the pieces is measured along the centerline of the core. The sum is then represented as a percentage over the length of the run and shown on the log as a percentage for each run. If the core is broken, by handling or by the drilling process, the broken pieces are fitted together and counted as one piece provided that they form the requisite length of 4 inches (100 mm).

A modified RQD can be used for larger core; core lengths counted in the sum are those whose length is two times the diameter of the core instead of the 4-inch (100-mm) criteria.

Table 5-4. - Relationship of RQD and Rock Quality

RQD (percent)	Description of rock quality
0 to 25	Very poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

3. Description of discontinuities. - Descriptors for discontinuities, excluding shears, are discussed below. The description of shear or fault zones is discussed in a subsequent subsection. Along with the physical measurements such as attitude (strike and dip) in exposures and orientation (inclination or dip) in drill holes and spacing where applicable should be information as to what kind of structure (or structures) cause the breaks; composition and thickness of fillings or coatings; character of surfaces (smooth or rough waviness); healing; and if possible, whether the discontinuity is open or tight. In drill core, the average spacing between fractures is measured along the centerline of the core or when a set can be distinguished (parallel or subparallel joints) is measured normal to the fracture surfaces. If more than one fracture set can be distinguished in the core, then they also should be recorded. Planar structural features, such as bedding planes, cleavage, and joints are not only necessary for describing the rock mass properties, but also may be used for correlation purposes along with flow structure, schistosity, lineation, etc. Descriptors provided in table 5-5 are suggested but may be modified to apply to project needs:

Table 5-5. - Terminology for discontinuity spacing

Spacing of discontinuities	Bedding plane, cleavage, joint, or fracture spacing descriptor
Less than 2 in (50 mm)	Very closely spaced
2 in to 1 ft (5 to 300 mm	Closely spaced
1 to 3 ft (300 mm to 1 m)	Moderately spaced
3 to 10 ft (1 to 3 m)	Widely spaced
Greater than 10 ft (3 m)	Very widely spaced

A complete description might be: closely spaced cleavage spaced 4 to 9 inches, average 6 inches. Joint set No. 1, widely to very widely spaced, spacing ranges from 7 to 15 feet, averages 10 feet.

Instructions for the Description of Shear and Fault Zones

Uniform and Zoned Shears

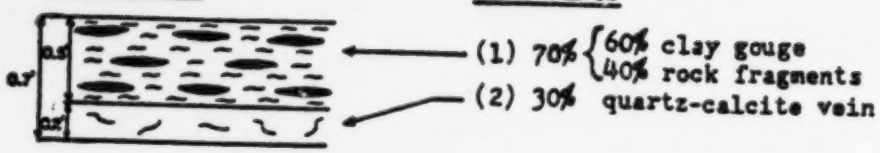
The composition of a fault or shear zone at a limited exposure can be described as either uniform or zoned. Illustrated below (fig. 1) is a 0.5-foot (150-mm) thick uniform shear with two components, which is composed of 40 percent rock fragments distributed relatively uniformly through 60 percent clay gouge.

Fig. 1. Uniform Shear:

In contrast, a zoned shear is composed of two or more zones (layers) which differ significantly in composition or have differing physical properties. A zoned shear could consist of the uniform shear described above and an additional 0.2-foot (60-mm) thick quartz-calcite vein along one contact as shown in figure 2.

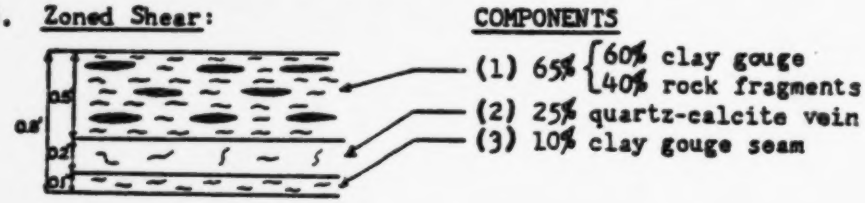
BEST DOCUMENT AVAILABLE

Fig. 2. Zoned Shear:



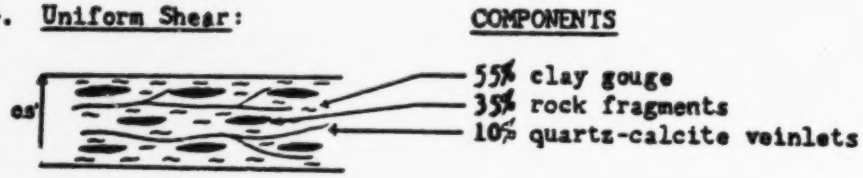
A more complex zoned shear might have a 0.1-foot (30-mm) thick clay gouge layer adjacent to the vein (figure 3).

Fig. 3. Zoned Shear:



Commonly, numerous small quartz-calcite or other mineral veinlets occur irregularly distributed throughout shears. The veinlets do not form distinct zones or layers; therefore, they should be considered a percentage component of a uniform shear as illustrated below in figure 4.

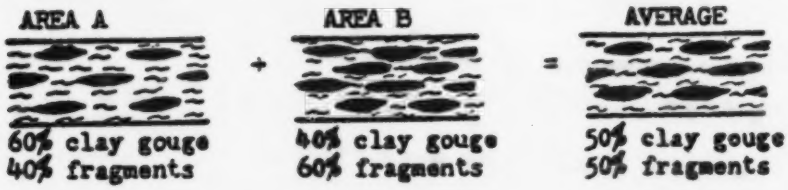
Fig. 4. Uniform Shear:



Shear zones commonly exhibit lateral variations in the percentages of components within short distances at an exposure. The shear zone illustrated in figure 1 could consist of 40 percent clay gouge and 60 percent rock fragments on an adjacent tunnel wall. Because the various components are not arranged in layers or zones, the shear is of the uniform type. If the exposure is limited, as in most tunnels or dozer trenches, the percentages of the various components should be averaged as illustrated in figure 5 and an average composition should be described.

EST DOCUMENT AVAILABLE

Fig. 5. Uniform Shear (Composite):



Descriptors and Descriptions of Shears

In order that shears are uniformly and adequately described at every exposure, it is essential that all geologic logs, whether core, trench, or tunnel, include a brief description of each applicable item listed below:

1. Thickness. - Report the true thickness measured normal to the shear contacts. True thickness can be measured directly or computed trigonometrically if a large zone. Indicate an average figure for minor variations and as a range and average for significant variations. Do not include associated features beyond the shear contacts or blocks of rock around which the shear has bifurcated as components of the shear thickness.

2. Attitude. - Measure true strike and dip (dip or inclination in drill core). Report an average figure if only moderate irregularities are present, but provide both a range and average if two distinct trends are apparent.

3. Composition. - Report on average percentage of each component. The various layers or zones of zoned shears may be indicated by use of bracketed numbers [i.e. shear 1(1), 1(2)] Describe each individual layer or zone in the order it occurs in the observation as if each zone were a uniform shear.

a. Gouge. -

(1) Percentage. - Report an average for each exposure or layer.

BEST DOCUMENT AVAILABLE

(2) Color. - Report only if it serves to distinguish varieties or indicates weathering.

(3) Moisture content. - Describe the apparent moisture content upon initial exposure using the following terms: very wet, wet, moist, dry.

(4) Consistency. - Report the ease with which gouge can be worked by hand: very soft (thumb penetrates gouge more than 25 mm if sufficient quantity), soft (easily molded, penetration of thumb about 25 mm), firm (easily crumbled, can be penetrated by thumb up to 5 mm), hard (can be broken with finger pressure, no identation with thumb, readily indented with thumbnail), very hard (cannot be indented with thumbnail).

(5) Composition. - Report the type of mineral(s), talc, chlorite, or mica, if known. Otherwise, report as clay if plastic or silt if nonplastic.

(6) Arrangement. - Describe whether the gouge occurs as thin coatings on fragments, as matrix between fragments, or as seams.

b. Fragments. -

(1) Percentage. - Report average percent by volume.

(2) Size. - Estimate or measure the least dimension of the most common fragment sizes that constitute the bulk of the shear and report a range. Use fractions of an inch and tenths of a foot, or metric equivalents.

(3) Shape. - Unless the distribution of several shapes is nearly equal, report only the most common shape using the following guide:

Angular . . . . .
Rounded . . . . .
Platy . . . . .
Lens-shaped . . . .
Wedge-shaped . . . .
Contorted . . . . .

(4) Surface features. - These should be included because they may affect or provide an indication of the strength of the zone or help to identify a particular zone in several exposures or observations. Descriptors include grooved, slickensided, polished, rough, chloritic.

(5) Lithology. - The identification of rock fragments (rock type) is essential, particularly if different from the surrounding rock mass or if several rock types are present in the zone. If fragments within the zone are weathered, this should be indicated.

(6) Strength. - Describe how the average-size fragment can be broken across its least dimension using the following format: can be broken with (very light, light, moderate, heavy) manual pressure or hammer blow.

c. Other components (vein or dike material). - Vein materials include, but are not restricted to, quartz-calcite and zeolites. Within the shear contacts these may be distributed and described either as a component of a uniform shear zone, usually occurring in the form of branching discontinuous veinlets less than 1/2-inch (13-mm) thick, or as a zone (layer) within a zoned shear. Dikes should be included as a single zone of a zoned shear if they are bordered by shear zones. They also should be described as a rock unit. If a shear zone occurs only along one border, then the dike should be described only as a rock unit.

(1) Percentage and thickness. - Report as an average or range for the exposure.

(2) Composition and texture. - Provide a brief description of mineralogy and texture (e.g., leached, vuggy) only if important structurally or for identification. Terms for the degree of fracture density may be reported here if the zone is a major component.

4. Healing. - Veins which compose distinct zones (layers) within a shear probably accomplish insignificant healing. However, small veinlets which are a component of a uniform shear zone and which actually form a bond between fragments increase the unit strength of the shear zone (see item 5 below). Healing must be determined by attempting to separate fragments manually or with a rock hammer. If fragments are actually bonded by some healing agent, the shear zone should be described as partly healed (less than 50 percent of fragments bonded), mostly healed (more than 50 percent of fragments bonded), and totally healed (all fragments bonded by vein material).

5. Unit strength. - The strength of the entire shear zone exposed in tunnels and dozer trenches should be reported by the ease of which the sheared material can be dug from the exposure. The following guide should be used: can be dug from wall, floor, or outcrop with (very light, light, moderate, heavy) finger pressure or hammer blow. Unit strength should be reported for each significant layer of a zoned shear.

6. Associated features. - Features outside the shear zone contacts are not considered a component of the shear zone but often are important. These should be described last and may include breccia or fracture zones, drag zones, or alteration or mineralization areas outside the contacts. Voids or zones of permeability with an estimate of any associated groundwater flow should be noted.

7. Example of shear zone description. - The following description of a shear zone in drill core is provided; actual description format may depend on type of log:

21.3 to 21.7 feet: Shear zone. 0.3 foot thick, upper contact dips 40°, lower contact dips 61°, averages 57° (parallel to bedding). Composed of 60 percent, green, moist, soft clay gouge and 40 percent 1/16- to 1/4-inch-thick platy and lens-shaped, slickensided, intensely weathered metashale fragments. Fragments partly healed by 1/32-inch quartz-calcite veinlet. Fragments break light manual pressure.

SECTION 6
INTERPRETATION AND PRESENTATION OF GEOLOGIC DESIGN DATA

The objective of this section is to establish a policy to encourage the use, evaluation, and portrayal of geologic design data to adequately describe the geologic conditions affecting design. To accomplish this objective, both factual and interpretative data must be used. These data must be presented in a three-dimensional format to be most beneficial to the design and construction process.

Factual data generally consist of specific information from drill holes, test pits, trenches, surface exposures, test data, etc. This information by itself is of minimal value to understanding the geologic conditions present at the site. The value of the factual data for understanding the geologic conditions that influence design and construction is enhanced by interpretation and presentation. This includes:

1. Projecting geologic contacts, discontinuities, and physical properties on plan and section drawings; and
2. Developing various contour maps depicting top of bedrock or top of lithologic units with significant or adverse properties, groundwater piezometric surface, structures, weathering, permeability, and isopach maps
3. Compiling statistical data for joints and fractures such as polar plots and contours (point diagrams), joint roses, and continuity and spacing of joint sets

Interpretative data, in conjunction with the factual data, provide a more complete picture of the geologic conditions and serve to point out weaknesses in the data base and the need for further investigations. Interpretative data also provide the means for relating geologic conditions to design and allows an avenue of communication within the Design Team.

The interpretative drawings and conclusions should be developed from an adequate data base consistent with the geologic complexity and nature of the engineering structure.

An adequate number of plan and profile drawings should be prepared to show all geologic conditions pertinent to the design. Factual information should be presented on these drawings so that the basis for interpretations can be evaluated. These drawings, at a minimum, should delineate the following:

- Surficial deposits and lithologic units
- Top of bedrock (if present)
- Weathering profile
- Ground-water conditions
- Geologic structure
  - Bedding or cleavage
  - Joint systems
  - Fault or shear zones
  - Folds

Other items should be added as needed. Appropriate symbols which may be used to display these data are provided in Appendix B.

These drawings should be at a scale which will clearly depict the geologic conditions and allow for interpretation and analysis. In most cases geologic sections and profiles with no vertical exaggeration should be used.

Factual data, such as geologic logs, should be submitted with associated interpretative drawings.

The gathering, interpretation, and presentation of geologic design data are dynamic processes requiring periodic submittals for review and evaluation, and continual updating of information. This process will facilitate communication between all Design Team members and will help result in final designs which reflect the geologic conditions.

SECTION 7

CHECKLIST FOR ENGINEERING GEOLOGY CONSIDERATIONS

This checklist is provided as a means to help identify important engineering geology issues that should be addressed during an engineering geology investigation. It is understood that many geologic phenomena are not singular in nature. They may be attributable to a combination of strength, deformational, chemical, and hydrological characteristics, and may be logically related to more than one element. Therefore, many of the checklist items belong under more than one heading and discussed or evaluated as such because they are themselves interrelated. The issues may be related strictly to geologic considerations (rock excavation versus common excavation, confined or unconfined aquifers), or more general (such as the need for engineering analysis or requirements for foundation during monitoring). However, a listing of items by elemental classification provides a rational framework by which engineering geology issues may be identified and thereby addressed.

Geomechanical Element

Stability of Earth Materials

This topic deals with the capability of earth materials to resist rupture disaggregation or disintegration, and therefore, the issues involve the strength of the material as well as the applied loads. Loads may be body forces (e.g., mass) or surface forces (e.g., loads imposed by or upon structures), and strength may be divided into strength of the material and strength of planes of weakness (including time and fluid pressure effects). The following is a checklist for stability of earth materials issues:

1. Loads and load patterns (static and dynamic)
2. In situ stresses
3. Strength of earth materials, layers, or zones (brittle, overconsolidated, plastic, viscous)

BEST DOCUMENT AVAILABLE

4. Strength variations due to water content
5. Shear strength as a function of cleft or pore pressure
6. Strength loss from blasting damage
7. Strength variations due to weathering
8. Dynamic strength (liquefaction and response)
9. Bearing strength
10. Slope stability (natural and cut)
11. Stress relief
12. Fracturing of foundations and embankments by drilling and grouting
13. Erosion (formation of rills, degradation, or aggradation of channels or wasteways)
14. Piping (washing of fines from soils or fractures, dispersive soils, etc.)
15. Sliding of structures
16. Overloading (compressing) of ground (fracturing, yielding, squeezing) in underground openings
17. Loosening (tensioning) of the ground in underground openings
18. Damage, deterioration, or slope instability due to construction activities
19. Ground collapse due to solutioning or mining
20. Rock or common excavation
21. Ability to be trimmed or shaped
22. Stability of construction roads and embankments
23. Excavation or drilling of boulders
24. Stability of borehole walls (grout, cassion, etc.)
25. Strength changes from freezing
26. Blasting techniques and fragmentation characteristics
27. Stability of trench walls (grout cap, pipeline, etc.)
28. Standup time in tunnels
29. Index (indirect indications of strength) requirements (RQD, density, PR, Atterberg limits, etc.)
30. Monitoring and instrumentation needs

Deformability of Earth Materials

This topic deals with the movement of earth materials, usually without rupturing, when subjected to load changes or because of nonlinear and time-dependent deformation characteristics. The following is a checklist for deformation of earth materials issues:

1. Load patterns (static, dynamic)
2. Deformation characteristics (moduli) of earth materials
3. Deformation moduli variations due to weathering or stress relief
4. Deformation moduli variations due to construction activities
5. Consolidation by loading or withdrawal of fluids
6. Beneficiation of deformable materials (grouting, treatments, refill with select materials, or other methods)
7. Rebound and heave
8. Differential settlement or expansion
9. Effects of permafrost
10. Ground sag
11. Fault movement in foundation
12. Squeezing and swelling ground in underground openings
13. Hydrocompaction - deep subsidence - fissuring
14. Ground support capability for construction machinery
15. Jacking (heave) due to grouting
16. Creep
17. Indices (indirect indications of deformation moduli) requirements (RQD, density, PR, etc.)
18. Monitoring and instrumentation needs
19. Subsidence of soils
20. Dispersive clays
21. Expansive clays
22. Organic soils

Geologic Fluids Element

This topic deals with the preconstruction, construction, and postconstruction geologic fluid regimes and their behavior.

Ground-water Occurrence and Behavior

This topic deals with ground-water regimes, as well as the anticipated behavior of subsurface waters during and after construction of a facility. The following is a checklist for ground-water issues:

1. Occurrence, definition, and number of aquifers
2. Confined or unconfined aquifers
3. Perched ground water
4. Configuration of piezometric surfaces
5. Primary permeability (transmissivity)
6. Secondary permeability
7. Storage coefficient (storativity)
8. Seasonal fluctuations of water levels and runoff due to precipitation or irrigation
9. Preferred seepage paths
10. Stress-relief permeability
11. Permeability change with time (solutioning, consolidation, deposition, piping along fractures, etc.)
12. Chemistry of ground water (Stiff diagram)
13. Temperature of ground water
14. Effectiveness of constructed subsurface water barriers (grout curtains, slurry trenches, etc.)
15. Effectiveness of drainage systems
16. Filter or drain criteria
17. Reservoir water-holding capability
18. Unwatering and dewatering requirements and effects
19. Groutability (type of grout; hole orientation, spacing, and depth; grout pressures and mixtures, etc.)
20. Grout travel

21. Drill cuttings sealing grout hole
22. Sediment in bedrock fractures impeding grout flow
23. Waterflows into and from tunnels and underground excavations
24. Index requirements (Lugeons, mechanical analysis, etc.)
25. Monitoring and instrumentation needs
26. Chemistry of reservoir water
27. Structure effects on ground water
28. Effects of ground water on structures, corrosivity, uplift, etc.
29. Ground-water withdrawal or recharge

Other Fluid Occurrence and Behavior

Similar issues pertaining to porosity, storage, occurrence, configuration of fluid reservoir, etc., provided under Ground-water Occurrence and Behavior are appropriate. In addition to those issues, the following is a checklist of other geologic fluid issues:

1. Dispersion potential of toxic fluids
2. Corrosion by liquid waste
3. Petroleum gases
4. Nonpetroleum gases
5. Crude oil
6. Contamination by or combustibility of natural, refined, or waste products (methane, gasoline, etc.)
7. Laboratory testing requirements
8. Monitoring and instrumentation needs

Geochemical and Geothermal Element

The geochemical and geothermal element pertains to both existing conditions and conditions to be imposed at a future date which may affect either the earth materials or affect man-made structures or materials by chemical or thermal agents. The following is a checklist for geochemical and geothermal issues:

1. Hydration of anhydrite
2. Solution of carbonates and evaporites
3. Chemical and mineralogical changes with time
4. Leaching of cementing agents
5. Ground conductivity (corrosion, grounding mats, etc.)
6. Adversity of chemical deposits (plugging drain holes, ocher clogging, etc.)
7. Corrosion potential
8. Fluid temperatures
9. Thermal expansion
10. Underground construction temperatures
11. Permafrost
12. Temperature effects on construction materials such as expansion, durability, and set of cement
13. Laboratory testing requirements
14. Engineering analyses required
15. Monitoring and instrumentation needs
16. Slaking

Geologic Hazards Element

Many of these issues should be identified early in the planning stages of a project, irrespective of the design concept, and further identified and resolved during the investigation and design phases. The most common geologic hazard issues are presented below:

1. Seismicity and faulting (includes reservoir-induced seismicity
2. Volcanoes and associated eruptions, landslides, mudflows, and seismicity
3. Landslides and avalanches
4. Crustal deformations (tectonic, collapse, consolidation, or expansion)
5. Erosion
6. Deposition
7. Glaciers

8. Flooding
9. Mine wastes
10. Chemical solutioning

Environmental Element

The environmental element pertains to both social and physical effects as a result of exploration or construction.

1. Buried objects of man, including explosive devices
2. Dust and mud
3. Inundation of mineral deposits and mine and mill tailings
4. Inundation or destruction of important paleontological, archeological, or geologic features
5. Sediment contributions and pollutants from shoreline development
6. Fracturing of wells adjacent to structure
7. Effect on springs, domestic water supplies, downstream estuaries, etc.
8. Benching, slumping, or landslides along reservoir shoreline
9. Waterlogging
10. Degradation and aggradation of downstream channel
11. Environmental factors of surface and subsurface geologic investigations, removal of vegetation, fire danger, pollution of aquifers or running water by drilling fluids or runoff from trenching, etc.

SECTION 8

RESERVOIR SITE GEOLOGIC STUDIES

The geologic adequacy of a proposed reservoir site is as important as the adequacy of a damsite foundation; reservoir-wide investigations must be planned with comparable care. Concurrent study of both reservoir and damsite(s) is best. If a major defect is uncovered in one or the other, investigations can be reoriented or stopped before a disproportionately large exploration investment accrues on a site which might or must be abandoned.

Introduction

In evaluating and, as necessary, exploring the reservoir geology, attention must be given to all factors which affect reservoir adequacy or use. Principal factors are rim stability, water-holding capability, bank storage, and potential sources of pollution. In addition, geologically related problems of relocation of highway, railroad, and other physical facilities must be considered. The degree of attention given to each of the several problems should be appropriate to its importance and to the stage of planning. The detailed character of investigations will, of course, be determined by the purpose of each specific reservoir.

An effective reservoir geologic map is an essential basis for planning and conducting the investigations. Inadequate geologic maps presenting incomplete, poorly chosen data waste money and technical manpower. Such inadequate maps may cause erroneous conclusions to be made or, because investigation time and money have been "used up," force binding decisions to be made on the basis of scanty data.

In some instances, multiuse geologic mapping might be accomplished advantageously through a cooperative agreement with other agencies such as the U.S. Geological Survey or State surveys. The cooperating agency might, for

example, prepare a general geologic map of the reservoir area: Bureau geologists, using that map as a base, would add data pertinent to specific engineering geologic problems and interpretations of the proposed reservoir behavior.

The following paragraphs present guidelines which will assist in accomplishing Bureau-wide consistency in handling the reservoir geologic investigations. These investigations and the resulting interpretative maps are needed in the successive planning, design and construction, and operational stages. See Reclamation Instructions, sections 133.3.2H(2), (3), and (4) and sections 133.4.2H(2), (3), and (4).

Basic Requirements for Reservoir Geologic Maps and Studies

On geologic maps prepared for engineering and related geologic studies, the range of data to be shown and the scale to be used will be determined by (1) the purpose of the investigations, (2) the detail that can be shown, and (3) the extent to which quantitative data must be presented or derived from the map such as distances, volumes of potential slide masses, thickness of formations, differences in elevation, or details of formation or outcrop boundaries. Choice of a suitable scale is important since it influences legibility of the map. Poor legibility may influence judgment decisions on problems such as reservoir rim stability and reservoir leakage including intake area, flow paths, and exit points.

In small-scale regional or project maps, the principal objective is to present a graphic picture of the general distribution of major site conditions; these may be geologic as well as existing manmade features such as highways and railroads, proposed dams, tunnels, or other engineering structures. In contrast, large-scale or site maps are detailed representations of geologic features. In the two types of maps, scales may range from 1 inch equals 10 miles (small scale) to 1 inch equals 20 feet (large scale). The usual reservoir map scale ranges from about 1 inch equals 2,000 feet to 1 inch equals 400 feet.

The reservoir geologic map(s) should not be restricted to the immediate area of the proposed reservoir. It must be supplemented by a regional-type map which will demonstrate the reservoir position, elevation, and distance to adjacent valleys. As a minimum, this map should show ridge and valley outlines with elevations.

The reservoir geologic map should be supplemented by several specialized maps or overlays and/or by larger scale inserts or separate maps showing detailed geologic conditions in critical areas of potential seepage or landslides. Similarly, small-scale skeleton inserts may be used to show gross relations of topographic saddles and adjacent drainages. Supplemental maps, charts, or graphs portraying regional ground-water contours or data (estimated if necessary) are desirable, particularly if potential leakage or anomalous ground-water conditions exist. Geologic sections and overlays showing generalized geologic structure, landslides, faults, buried channels, etc., should also be prepared.

The basic reservoir mapping, at least on a reconnaissance basis, must extend above the maximum reservoir level to characterize the geologic environment and facilitate evaluation of reservoir-rim stability and water-holding capability. There may be extensive areas below minimum reservoir level in which appraisal study mapping will be entirely adequate, or perhaps no mapping at all will be necessary. In local areas of the reservoir, more detailed mapping may be necessary to define landslide or leakage problems. In many cases this will be required only in critical areas.

Only in occasional cases or in certain types of terrane will the entire reservoir require detailed mapping and study. Commonly, the study and detailed mapping will be accomplished only so far as needed to establish the geologic adequacy and principal defects.

Methods of Investigations

Field examinations and air photograph interpretation are the basic methods by which geologic data are secured and collated on map(s) and section(s) for study and interpretation. The reservoir geologic map is the initial and principal medium through which geologic studies are planned or conducted and by which the nature and scope of reservoir defects are recognized and evaluated.

The "map" may range from a sketch presenting the composite mental concept developed by a geologist during early reconnaissance and appraisal field studies, to a complete, detailed delineation of lithologic and structural features for feasibility and final design. Whatever the stage, the product is a combination of fact and interpretation which, from an engineering geologic viewpoint, defines the geologic environment and aids in recognizing geologic defects or issues. Direct subsurface investigations such as drilling may or may not be a part of the overall study. Hydrogeologic conditions must be considered and defined. Thus, an effective reservoir map is more than a representation of surface information. It should also show selected subsurface interpretations of geologic and ground-water conditions which characterize the reservoir site.

A variety of techniques or investigation approaches can be used in conducting reservoir studies. The annotated outline which follows is presented simply as a checklist of principal techniques which will assist even an experienced geologist in recalling or selecting the several investigation methods which will be most effective in conducting a specific reservoir site study.

It is assumed that reservoir studies will be planned and conducted by engineering geologists and ground-water geologists trained in basic geologic principles and in standard methods of geologic investigation. Furthermore, it is assumed that if they have not already done so, the geologists will secure advice or familiarize themselves with various texts, publications, and reports describing special investigation methods.

Geomorphologic Interpretation

Stream patterns, topographic and geologic maps, and aerial photographs can provide information such as:

(1) Geologic structure, regional and local joint patterns, location of geologic contacts, sinkholes, and subterranean drainage.

(2) Glacial, fluvial, and aeolian deposits.

(3) Aggrading stream history producing deep valley fill; degrading stream history producing destructional landforms such as gravel-veneered (aggregate deposits) or rock-defended (low aggregate volume) terraces.

(4) Potential sources for embankment materials.

(5) Ground-water conditions; reservoir leakage potential.

(6) Existing and potential landslides.

Hydrogeologic Studies

These studies yield information or require analyses such as:

(1) Fundamental ground-water conditions, i.e., whether water bodies are perched, semiconfined, etc.

(2) Ground-water velocities, direction of flow, elevations, and contours of static and piezometric water levels can be determined using methods such as drill hole water level measuring devices, down-hole flowmeters, dye and radioisotope tagging, and water sampling and analysis.

(3) Ground-water ages (relative) as determined by tritium, carbon dioxide, or dissolved oxygen content.

(4) Differentiation of ground-water bodies and evaluation of water quality by chemical analyses (analyze graphically by Stiff diagrams), conductivity, pH, and temperature studies.

(5) Flow estimates or measurements of springs and small watercourses. Data such as springflow and volume, and ground-water levels in drill holes may be essential to define changes in the original ground-water conditions due to reservoir leakage. Data collection must be started and completed in advance of reservoir filling to establish the character of normal prereservoir conditions. Measurements of hydrostatic head may be necessary to judge whether springflow may be reversed when subject to reservoir head.

(6) Estimates of bank storage volume, inflow and outflow rates.

Subsurface Investigations

Subsurface investigations may include geophysical tests; bailing tests as needed to determine water table elevations and movement; packer or pump-out tests to estimate permeability, or exploratory drilling to obtain landslide thickness, depth and nature of surficial material in saddles, location of buried bedrock channels, or glaciofluvial permeable outwash channels in tight till deposits.

Remote Sensing

Natural color or false color infrared airphotos or sidescanning radar imagery may be of assistance in mapping contacts, landforms, or geologic structures. Infrared imagery detects surface geothermal anomalies which may be indicative of near-surface ground water, faults or lineaments, and contacts.

Collection and Presentation of Data

In the following discussions are some geologic conditions which must be considered in field examinations and mapping for the "average" reservoir. Those actually chosen for investigation or, because of their bearing on reservoir problems, for presentation on specific reservoir geologic maps will depend on a variety of factors, some of which were outlined in previous paragraphs.

Distribution of Bedrock and Surficial Deposits

Studies should differentiate between major areas of surficial deposits such as talus, slopewash, alluvium, and glacial deposits. Particular attention should be given to differentiating and mapping those units which will have different or adverse engineering properties. Thus, in alluvial and glacial materials, one should distinguish between those which are free draining such as terrace gravel, sand, or coarse talus, and those which will drain slowly such as silt, clay, fine-grained slopewash, or till. Areas or materials which will be susceptible to erosion by wave action should be delineated.

Discontinuities and Structural Features

Regional (orogenic) joint systems and localized joint patterns should be ascertained. Their attitudes as well as those of bedding or foliation should be described and shown on maps, particularly in areas of proposed construction and in the vicinity of existing or potential landslides.

Stress relief joints and fractures patterns are significant; outline areas affected, and map dominant joint dip and strike. Individual joints need not be shown.

Major structural features such as anticlines and synclines should be identified.

Major faults, shear zones, and lineaments should be identified early in the data collection process. Relative ages and structural relationships should be noted. This is important in the planning stage so that seismotectonic evaluations may be performed early in the design process.

Ground-water Occurrence and Behavior

Artesian and pumping wells, springs, seeps, swamps, ephemeral lakes, and snow avalanche paths should be located and studies performed as described in a previous subsection.

Mineral Resources

Mineral prospects and claims; active and inactive drifts, mines, and quarries; sand and gravel pits; oil and gas wells; waste dumps; and other resource development or potential development should be discussed and features identified on the reservoir map(s).

Observed and Potential Geologic Hazards

Observed and potential subsidence, settlement, and reactivation of faults resulting from man's activities, such as hydrocarbon and ground-water withdrawals, reservoir-induced effects, etc., should be addressed.

Buried Conduits

Identification of buried conduits and pipelines for communications, oil, gas, and water, although not geologic in character, may aid the engineer in planning highway or railroad relocations or other construction involving excavation or fills.

Landslides and Rim Stability

Identify existing landslides, state whether active or inactive, and show boundaries. Describe slide debris, estimated slide depth, and site geologic

conditions. Areas of potential landslides should also be identified. Show probable boundaries or limits of potentially unstable material and estimate depths and volumes for use in judging right-of-way requirements, freeboard requirements, and locations of other features. Additional discussions on this topic are presented in a subsequent subsection.

Reservoir Integrity and Potential Leakage

Widths of ridges and saddles at the reservoir flowline between the reservoir basin and adjacent valleys and drainage ways should be examined. Physical properties of the materials and geologic structure in these areas should be determined. This includes the position of permeable or soluble formations, or joint systems which will be exposed to reservoir water and which bypass the damsite and grout curtain or extend into adjacent valleys.

Ancient buried channels (alluvial- or lava-filled) that may bypass the damsite or lead out of the reservoir basin should be identified.

Anomalous ground-water levels may be an indicator of potential reservoir leakage paths. Therefore, static water-level measurements are essential for the determination of reservoir feasibility.

Sources of Contamination of Reservoir Water

The potential for contamination of reservoir waters by soluble minerals such as halite, gypsum, alunite or arsenic-bearing ores, mill tailings and mine dumps, acidic mine water, oil-field brines, industrial wastes, and animal waste should be ascertained.

Reservoir Characteristics

Preceding paragraphs have outlined many of the types of information, analyses, and basic geologic data which should be included in the report and/or be shown on a reservoir geologic map. Attention has been growing on the

increased importance of two facets of engineering geologic investigations for reservoirs, reservoir rim stability and water-holding capability. Engineering planning, both now and in the future, will give increasing attention to reservoir sites which will present serious rim stability problems or be prone to leakage with consequent increased risks of property damage, injuries, and, possibly, loss of life. For such studies, the reservoir geologic map is an essential base for recording pertinent data. It is necessary for the formulation and completion of both types of investigations and is essential for evaluating the relative landslide risks and water-holding capability.

Reservoir rim stability and leakage become particularly difficult to recognize and evaluate for sites: (1) in rugged, mountainous terrain where slopes are in quasi-equilibrium and (2) where rapid reservoir-level fluctuations will be inherent in the engineering operation, such as storage of floods, production of peaking power, and in pump storage for power generation. In these problems, sound evaluations and conclusions require that pertinent geologic facts be clearly presented on geologic maps and appropriate interpretive sections.

The following paragraphs give more specific guidelines for recognizing and recording mappable geologic units and, to a limited degree, for the interpretation of those data.

Reservoir Rim Stability and Landslide Classification

Evaluation of the relative stability of the rim of a proposed reservoir is a difficult problem. The evaluation involves the determination of both existing and potential landslide areas and the evaluation of the proposed reservoir operation. The first is basically a mapping procedure involving interpretation; the second is principally interpretation based on the results of the mapping and other pertinent data.

In developing the reservoir rim stability data for the geologic map, particular care must be given to those rim reaches in which landslides might result in loss of life and damage to private property or engineering structures.

If the reservoir is small and existing or potential slides are large, the investigator should provide an estimate of the loss of active storage anticipated during the life of the system. The seismicity of the region in which the reservoir is located must be considered in judging reservoir rim stability.

The paragraphs below give guidelines and criteria for classification of reservoir rim stability.

Group A, active slide areas. - This category includes slides that have moved within the last 10 years. Steps may have already been taken to stabilize some of these areas to protect highways or other physical features, but unless they have been stable for at least 10 years, they must still be classified in this group. Group A is divided into two subgroups:

Subgroup A-1. - These slides require attention during design and construction. Remedial treatment may be required for all slide areas located in the vicinity of proposed damsite(s) and at or near appurtenant structure sites; along roads and highways, transmission lines, and canals; in the vicinity of probable concentrated recreational and camping areas; and slide areas, regardless of their location, which are of sufficient size that the slide mass or the water waves created at failure might result in damage to structures, obstruction of the reservoir, or loss of life.

Subgroup A-2. - This subgroup includes all slide areas located in remote sections of the reservoir where structure damage or loss of life is unlikely. They involve areas ranging up to 500 feet in width and extending at least 50 feet above proposed reservoir surface. If larger, they should be included in subgroup A-1. Fencing or signs and buoys to warn or prevent access by campers, fishermen, or boaters may be employed in lieu of remedial treatment.

The general geologic information necessary to evaluate the nature and cost of possible remedial measures for landslides in subgroups A-1 and A-2 would include detailed surface geologic mapping. The delineation of landslide boundaries and geologic conditions in the vicinity of the slide should be

shown on the reservoir geologic map if the scale will permit. If not, it should be portrayed on an insert or on a separate map. Special attention must be given to those geologic factors which may have caused the slide, e.g., weak materials such as severely jointed rock, shearing, soft clay, clay shales, or permeable but slow-draining material such as silt or silty sand which might develop high pore pressure during rapid reservoir drawdown. Structural conditions with unfavorable attitudes such as joint systems (including stress-relief joints), faulting, bedding planes, schistosity, and lithologic contacts should be identified. Prepare a section through the slide normal to the reservoir edge.

The map data and geologic cross section(s) presented should be those which would facilitate weighing the relative merits of remedial measures such as providing surface and subsurface drains, loading the slide toe, or unloading the top of the unstable area.

The map and geologic section(s) should portray the present limits of the slide, its depth, and the estimated probable headward growth or upslope encroachment of the slide during the first few years (5 to 10 years) of reservoir operation. Any geologic or other reasons for anticipated limited headward growth should be described.

Numbering the slide areas or individual slides might be considered so that descriptions of materials, geologic conditions, etc., may be more easily discussed.

Group I, slide areas inactive for at least the last 10 years. - All slides, large or small, even though inactive for at least the last 10 years, are significant because they may be reactivated by reservoir drawdowns or construction activities. Their temporary inactivity may be because they have not been subjected lately to the condition which originally caused the instability; they have become stable for unknown reasons; or they have been stabilized by remedial measures.

BEST DOCUMENT AVAILABLE

The same general geologic map data and details required for group A should be provided for evaluation of group I slides.

Group P, potential slide areas. - This group must include reaches of the reservoir rim which, because of combined conditions of saturated material and unfavorable topography, might become unstable when subjected to reservoir operating conditions. The term "slide area" as used in this group should be interpreted as including all potentially unstable masses along the reservoir rim. These may range from large rock falls in steep cliff areas to shallow surface slides in gently sloping areas.

The same general geologic map data and details required for group A should be supplied.

Group F, rockfall areas. - Areas where rockfalls occur or potentially could occur are in this group. The same general geologic map data and details required for group A should be supplied.

Reservoir Water-holding Capability

Geologic investigations of all potential reservoirs must include a determination of probable water-holding capability. Procedures applied should be suitable to local conditions and the stage of the investigations.

Early geologic investigations must be in detail sufficient to demonstrate that the reservoir will be reasonably watertight and that the expense of feasibility and later geological investigations to obtain evidence of water-holding capability and the estimate of probable leakage losses is warranted. Conversely, early investigations should demonstrate that the reservoir site is unacceptable if excessive leakage is probable.

Later geologic investigations for reservoir watertightness must be sufficient in scope and detail to support firm conclusions. If the reservoir is expected to leak, there must be an estimate of quantity in terms of one of the following: (1) whether loss will be less or greater than hydrologic

accuracy and whether it will significantly affect estimates of reservoir yield; (2) a conclusion that, although the loss cannot be accurately estimated, it will not be so excessive as to adversely affect project economics and that losses can be reduced or controlled by treatment, or can be recovered; or (3) a reasonably reliable numerical figure which may be used in water-supply computations. Analyses of reservoir losses should include bank storage, loss outside the watershed, and possibilities for recovery by reason of return to the stream above points of diversion or to areas subject to ground-water pumping.

These more detailed investigations may require reservoir drilling and water loss tests, observation wells, observation around the reservoir periphery, testing of materials for hydraulic properties, as appropriate in each individual case to secure information supporting a reasonably conclusive finding. The geologic investigations should also include consideration of other factors such as possible increases in loss through piping, or solution, or reduction in loss after filling by natural sealing processes.

A reservoir geologic map - suited to the level of investigation - is essential for judging the capability of a proposed reservoir to retain inflows to meet project needs. The map with related geologic sections provides reviewing engineers and geologists with three-dimensional relationships of factors such as seepage routes, rates, and location of areas of intake and exit. Accordingly, the specific reservoir map may need to be supplemented by inserts, separate maps or sections showing geologic details and subsurface conditions such as attitude and elevation of the ground-water surface.

Geologic map data are basic to evaluation of: (1) feasible methods of diminishing seepage losses, (2) damage by high ground-water levels in the seepage exit area; (3) possibility of recovering leakage for project use or whether it will be lost to the project but return to the river system; and (4) an investigation, drilling, and field testing program required to provide valid, quantitative answers.

The specific data to be presented in any one instance will be determined by geologic conditions and other factors. The conclusions and opinions relative to the reservoir water holding capability given in the geologic report must be accompanied by a presentation of the facts and interpretative reasoning on which they were based.

SECTION 9
GEOLOGIC DESIGN DATA REPORT

This section sets forth the guidelines to be used in the preparation of the Geologic Design Data Report. This report is now a prerequisite to initiating designs for specifications as stated in Reclamation Instructions 133.4.1. Though the report is to be prepared by Regional or Project Geologists, the Responsible Geologist assigned to the specifications is to ensure that the content and coverage of the report for designs, for which the ACER has responsibility for, conform to these guidelines. Because the report must be approved by the E&R Center, it is in the best interest of the originating office and the Responsible Geologist to coordinate and cooperate continually during data collection and the preparation of the report so that omissions of required data or last minute problems do not arise that might delay submittal or approval, and subsequently delay specifications preparation. Input to the report must be sought from all involved.

The intent of the Geologic Design Data Report is to (1) formalize the submittal of geologic design data, (2) furnish geologic information to the designers at the start of design, (3) provide geologic design and construction considerations, and (4) submit the geologic design data to a review process to ensure technical adequacy.

Submittal of the Report

The Geologic Design Data Report is due on the GEOLOGY data date (DATA-G date) shown in the Denver Office Specifications Schedule). This is normally the same date as the DATA date on the Denver Office Specifications Schedule, DC-1A. If no GEOLOGY date is shown, it is assumed to be the same as the DATA date. It is recognized that for many designs the collection of geologic design data must continue into the design phase. If exploration is incomplete, a Geologic Design Data Report still must be submitted at the DATA date and an Amended Geologic Design Data Report at a later date as discussed below.

If there is agreement that both an original and amended report are permissible, both reports must be submitted to the review process and both reports must be complete and address all the required geologic design data, data collection, conclusions, and geologic considerations as of the date of their submittal. If the initial report is submitted on the DATA date, then the amended report will be due on the GEOLOGY data submittal date (as shown in the Denver Office Specifications Schedule) agreed upon by codes D-210 and D-1600 and the appropriate field offices. This new GEOLOGY date must be no later than 60 percent of the time between DATA and SPECB for an IFB date of a specification not to slip. The use of supplements is discouraged. However, if special studies or additional exploration occur after the amended report has been prepared, subsequent exploration data would be submitted by supplements. These procedures will allow the report(s) to discuss results of exploration for final designs rather than feasibility or preliminary design concepts and would eliminate the discussion of additional studies, renumbering of stations on logs of exploration due to changes of alinement, etc. Early scheduling of the geologic investigations program and the early delegation of responsibilities for the preparation of the Geologic Design Data Report will greatly facilitate the timely completion of the program and ensure proper participation (see section 3, Engineering Geology Review Memorandum). Every attempt should be made to complete all or a significant portion of geologic explorations prior to the design DATA date. If it becomes apparent during the exploration program that the investigations will not be completed according to the schedule, the Responsible Geologist should be notified so that priorities can be assigned to the remaining investigations if necessary. Data collected prior to submittal of the Geologic Design Data Report may be transmitted officially or by blue envelope to the E&R Center through the Responsible Geologist. Data submitted informally, or officially submitted in "preliminary" form must still be resubmitted in the formal submittal of the Geologic Design Data Report. If additional investigations are to be performed during the design phase, they should be directed to answering specific engineering geology issues or to specific explorations and should be accomplished in time to meet the designer's needs. These later investigations should be defined in the report. If the additional work cannot be clearly stated or defined, or the investigations have not proceeded

to a point where a meaningful report can be prepared, the design DATA date must be slipped to a time which will permit the preparation of a report which adequately addresses the engineering geology issues. The impact of this slippage upon the IFB date must be determined and the IFB date slipped also, if necessary.

A construction materials report is distinct from a Geologic Design Data Report. However, construction materials data relevant to the geologic data should be included as part of the geologic design data. The construction materials report can be submitted as an appendix to the Geologic Design Data Report if the ACER and project or region offices agree it is appropriate. The geologic content of the materials report will then be subject to the same approval process as the geologic design data.

Review of the Geologic Design Data Report by the Responsible Geologist and the Regional or Project Geologist should take place prior to the DATA date, which is to be determined jointly by codes D-210 and D-1600, and the field. This review must take place early enough before the due date to incorporate any changes or revisions. This review may consist of round table discussions for the more complex geological settings. Approval of the report will be by memorandum. Sufficient copies (four to seven as determined by the Responsible Geologist) of the approved report should be transmitted to the Division of Geology for distribution.

The geologic specifications paragraphs, drawings, and Records of Subsurface Investigations will be prepared from data presented in the approved Geologic Design Data Report by the Responsible Geologist.

General Comments on the Report

Content of the Report

The Geologic Design Data Report should contain all the necessary geologic information and evaluations required to design all the features of and

prepare specifications for bidding and constructing a facility. Other sections of this guide discuss or provide guidelines for terminology, description, collection, and presentation of geologic information. The information contained in the report must represent established geologic concepts and be capable of being substantiated by sound geologic reasoning. Geologic evaluations and interpretations are necessary in engineering geology and should be well developed and used in the report to the extent necessary to adequately address the geologic conditions and engineering geology issues at the site. However, these evaluations and interpretations should not be stated or represented as established geologic fact or as unequivocal.

The authors of the report and, if possible, a geologist from the region who is familiar with the job should critically review the narrative, the logs of explorations, the drawings, and any test data sheets for content, adequacy, and consistency in terms and numbers.

Drawings

All drawings should be prepared as standard-sized drawings to facilitate their incorporation in or adaptation to the specifications. The set of geologic drawings should include a drawing titled "General Geologic Legend, Explanation, and Notes," which is the major reference for the other geologic drawings (see recent DC specifications). Appropriate symbols and explanations or notes should be used to portray and qualify subsurface geology to avoid representing interpretations as unequivocal fact. All plan and section drawings shall be prepared in accordance with Section 6, Interpretation and Presentation of Geologic Design Data.

General Outline

A general outline for a Geologic Design Data Report follows. This outline may vary from site to site because of type of structure (e.g., dams, tunnels, canals) or geology. Therefore, judgment and discretion must be exercised in the preparation and formulation of the report.

BEST DOCUMENT AVAILABLE

Title page
Approval page
Preface
Table of contents
    List of plates, photographs, drawings, drill logs, material test data, etc.
Introduction
    Purpose
    Location
    Proposed structures
Geologic investigations
    Previous investigations
    Current investigations
    Testing and sampling
Regional geology
    Stratigraphy
    Structure
    Regional ground water
Seismicity
Site geology
    Stratigraphy
    Structure
    Geomorphology
    Ground water
Reservoir geology
    Water-holding capability
    Rim stability
Geologic considerations
    Geomechanical element
    Geologic fluid element
    Geochemical and geothermal element
    Geologic hazards element
    Environmental element
Additional investigations
References

Appendixes

Testing and sampling data

Exploration logs

Drawings

Photographs

Comments on General Outline

Title page. - See example at the end of this section

Approval page. - The approval page provides signatory approval by the author(s) and, depending upon regional policies and delegation authority, by the Project Geologist, Project Construction Engineer, Regional Geologist, or others (see example at the end of this section). Additional signatory approval will be completed by the E&R Center either by insertion of the approval memorandum and/or signatures and titles.

Preface. - A preface is a statement written by the author giving credits and acknowledgements, and the names of the geologists who contributed to the report.

Table of contents. - A table of contents lists the headings appearing in the report with the relative rank of headings indicated by indentation. Under the table of contents list all plates, photographs, figures, drawings, drill logs (with photographs if included), logs of other explorations, materials test data, other test and geophysical data, etc. Anything interspersed in the text or included in an appendix must be listed, including each log with its number of sheets.

Introduction. - The introduction should state the purpose of the report and the location of the site and proposed structures. The introduction should also include a project location map showing the features and, if possible, aerial photographs showing the general area.

BEST DOCUMENT AVAILABLE

Geologic investigations. - This section should include reasons for conducting all geologic investigations such as drilling, testing, mapping, geophysics, etc., performed by the Bureau, other agencies, or individuals and any previous construction work pertinent to the area under consideration. A statement should be included that all data about the site from previous reports are included in the report. Reference should be made to selected reports pertaining to the geology of the area prepared by other organizations or persons. Include descriptions of all geologic and/or geophysical field testing, sampling, and other studies done that are pertinent to the site. The raw data should be included in the appendix.

If a report by the Division of Research or other laboratory has been or will be prepared on some or all of the testing and sampling, the report(s) should be referenced but all of the information not duplicated in the Geologic Design Data Report.

Regional geology. - Knowledge of the regional geology is of value insofar as it helps provide a conceptual model to assist in interpreting the results of an exploratory program and in extrapolating from known data. It also provides a basis for comparison with other similar sites. The regional geology should be written in succinct paragraphs that are relevant to the site. Illustrations and references should be cited as appropriate.

Seismicity. - For critical structures, the Seismotectonic Section at the E&R Center will prepare an earthquake hazards evaluation of the site. The need for scheduling a separate seismotectonic report will be determined at the start of design data collection. In the Geologic Design Data Report, mention should be made that this work has been completed or is scheduled for completion by a certain date (usually the DATA date).

For noncritical structures, a description of the historical earthquakes and related ground motions which have affected the site or project area should be presented. Discussions should include historical movement on faults, historical seismicity in the vicinity of the site, and any known geologic evidence pertaining to ages of fault displacement. Also, indicate

the level and probability of ground shaking at the site from A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States by Algermissen and Perkins. 2/ An excellent reference for historical earthquakes is Earthquake History of the United States. 3/

Site geology. - Site geology is the recognition and delineation of specific geology in the area of the particular features to be constructed. Separate sections may be written for the various features. The site geology includes a description of the local stratigraphy and structure which will be encountered during construction and the quality and characteristics of the foundation materials. This should include discussions of detrimental qualities or planes of weakness such as joints, bedding planes or cleavage, faults and shear zones; weathering; surficial deposits to be encountered, excavated, stockpiled, or wasted; ground water; and any special conditions such as landslides, expansive or dispersive materials, subsidence, presence of oil or gas, and mineral extractions. In the discussion, refer specifically to geologic drawings (plans and sections), logs, test data, tables and photographs of particular geologic conditions, all of which should be included in the report. Avoid ambiguous words such as probable, any, maybe, perhaps, apparent, can, and could be. Terms should be defined and consistent between the narrative and supporting data (e.g., intensely fractured, moderately weathered, closely spaced - see section 6). The liberal use of photographs is encouraged.

Geologic opinions, interpretations, or conclusions should be stated in the report but they must be defensible and based on facts or documents supportable enough to be defended if challenged. It is incumbent upon the geologist

---

2/ Algermissen, S. T., and D. M. Perkins, A Probabilistic Estimate of Maximum Accleration in Rock in the Contiguous United States, Open-File Report 76-416, United States Geological Survey, 1976.
3/ Earthquake History of the United States, Publication 41-1, rev. ed. through 1970, National Oceanic and Atmospheric Administration, 1973, and the 1971-1976 Supplement, 1979.

to continually conceptualize and hypothesize the subsurface conditions to better comprehend and describe the impact of geology upon the design and construction of the features and to better direct the investigation effort.

If ground water or other special considerations, such as landslides, faulting, or subsidence, are considered to be of particular significance they may warrant a main heading and complete discussion. For example, under the heading, "ground water," describe the nature of the aquifer(s) indicating any perched, artesian, or seasonal water tables and water level fluctuations. Refer to percolation or permeability tests, water level readings, hydrographs, related charts or information, etc. If water level measurements were obtained at completion of drilling, indicate whether or not the hole was bailed prior to measuring. Ideally, these measurements should be made over a significant time period to determine seasonal fluctuations.

Reservoir geology. - If appropriate, a reservoir site study should be included and should be conducted in accordance with section 8, Reservoir Site Geologic Studies.

Geologic considerations. - The intent of this section is to discuss separately all the geologic issues pertinent to the design and construction of the engineering features and to present an evaluation of the issues. Address the geologic condition to be encountered, stressing identifiable problems, presenting solutions or recommendations, and the need for monitoring or verification, particularly during construction. Section 7 provides a checklist for the more common issues.

For most major structures, the Responsible Geologist will prepare a final memorandum describing the geologic design and construction considerations after all design concepts and criteria are known. This memorandum will reference all geologic data used in the design including the Seismotectonic Report and the Geologic Design Data Report.

Cooperation between all involved offices in the preparation of the geologic design and construction considerations is essential, and issues should be defined and resolved as early as possible.

Additional investigations. - Any geologic investigations which are to be performed after preparation of the Geologic Design Data Report should be discussed.

References and/or bibliography. - Pertinent references and/or a bibliography should be included.

Appendixes. - Appendixes should include all supportive data not included in the body of the report.

(Sample Title Page)

GEOLOGIC DESIGN DATA REPORT

for

(FEATURE)

(PROJECT)

(STATE)

(AUTHOR)

(DATE)

United States
Department of the Interior
Bureau of Reclamation
(Office)

(Sample Approval Page)

This Geologic Design Data Report was prepared in the (Office) by:

(Name) (Title)	(Name) (Title)	(Name) (Title)

Field approval by:* (Name), (Title) (Date)

(PCE/Regional Geologist, etc.)

(Lower half of the page blank for entries by the E&R Center.)

* Field approval as per Regional policy.

SECTION 10
SIGNATORY AUTHORITY AND SIGNATURE BLOCKS FOR GEOLOGIC DRAWINGS

This section discusses the signatory authority for specifications geologic drawings and overlays and appropriate signature blocks. This section augments Assistant Commissioner - Engineering and Research Memorandum No. 19, Signatory Authority for Design Drawings, dated September 17, 1980.

Signatory Authority for Drawings

For specifications involving more than a few explorations, consideration should always be given to include two specialized drawings, in addition to geologic overlays on designer base drawings and other geologic drawings: one showing the location of explorations and the other showing general geologic legend, explanation, and notes. Both of these drawings will usually be signed "approved" by the Chief, Division of Geology. Other geologic drawings or overlays to be signed "approved" by the Chief, Division of Geology, include the following:

1. Dams
2. Major powerplants
3. Major pumping plants
4. Tunnels
5. Siphons
6. Major bridges
7. Large buildings
8. Canals (except plan and profile sheets)

Drawings not identified for approval by the Chief, Division of Geology, will be signed "approved" by the appropriate Geology Branch Chief. Typical geologic drawings to be signed by the Chief, Western Geology Branch, or the Chief, Central Geology Branch, include the following:

1. Minor powerplants
2. Minor pumping plants
3. Transmission lines
4. Substations and switchyards
5. Minor bridges
6. Small buildings
7. Plan and profile sheets for canals and distribution systems

All signatures and initials within the title block should be in waterproof ink.

Signature Blocks

This discussion complements the Assistant Commissioner - Engineering and Research Memorandum No. 19. Figures 6, 7, 8, and 9 show the title blocks and signatory approval to be used for the drawings prepared for or by the Division of Geology for ACER specifications.

Engineering drawings prepared in the E&R Center that have geology shown on them shall have the signature block shown in figure 6. If geologic information is depicted on an overlay(s), which will be printed in color, the geology title block should also be on the overlay(s). However, if the geologic information is depicted on the base, which will be printed in black, then the geology title block should be on the base.

Engineering drawings prepared for the E&R Center by regional, project, or field offices that are included as part of the E&R Center specifications and will be signed as "Approved" in the E&R Center, should be signed for "Field Approval" prior to being transmitted to the E&R Center. When geology is shown on them which has been prepared by the Division of Geology, E&R Center, a modified signature block as shown in figure 7 is used.

Engineering drawings prepared by field offices which are included as part of E&R Center specifications will be signed as "Approved in the E&R Center." These drawings should be signed for "Field Approval" prior to being transmitted to the E&R Center. When geology is shown on them which has been prepared by the field office, a modified design signature block and geology signature block are used as shown in figure 8. "Field Approval" for the geology title block would be signed Project or Regional Geologist, and Technical Approval will be signed by the Responsible Geologist.

Specifications drawings involving only geology may have "Geology" substituted for "Designed" in the signature block. If there is inadequate space in the title block for all of the names of the geologists who prepared the geology, "Project Staff," "Region Staff," or "E&R Center Staff" may be used, and the geologists' names should be referenced in the drawing notes (who and when).

Geology drawings prepared by the Division of Geology for E&R Center specifications and reports will use the signature block shown in figure 9. "Technical Approval" will be signed by the Responsible Geologist.

Geology drawings prepared by the field, which are included in E&R Center specifications, shall have the signature block shown in figure 10. In this case, "Submitted" and "Recommended" on the main title block would be signed by the geologist who prepared the drawing or the Project Geologist. "Approved on the main title block would be signed by the Field Engineer, Project Construction Engineer, or Regional Engineer or Geologist (depending on delegation of authority). "Technical Approval" in the small "Geology" title block will be signed by the Responsible Geologist who is accountable technically for the geologic information depicted on the drawing.

BEST DOCUMENT AVAILABLE

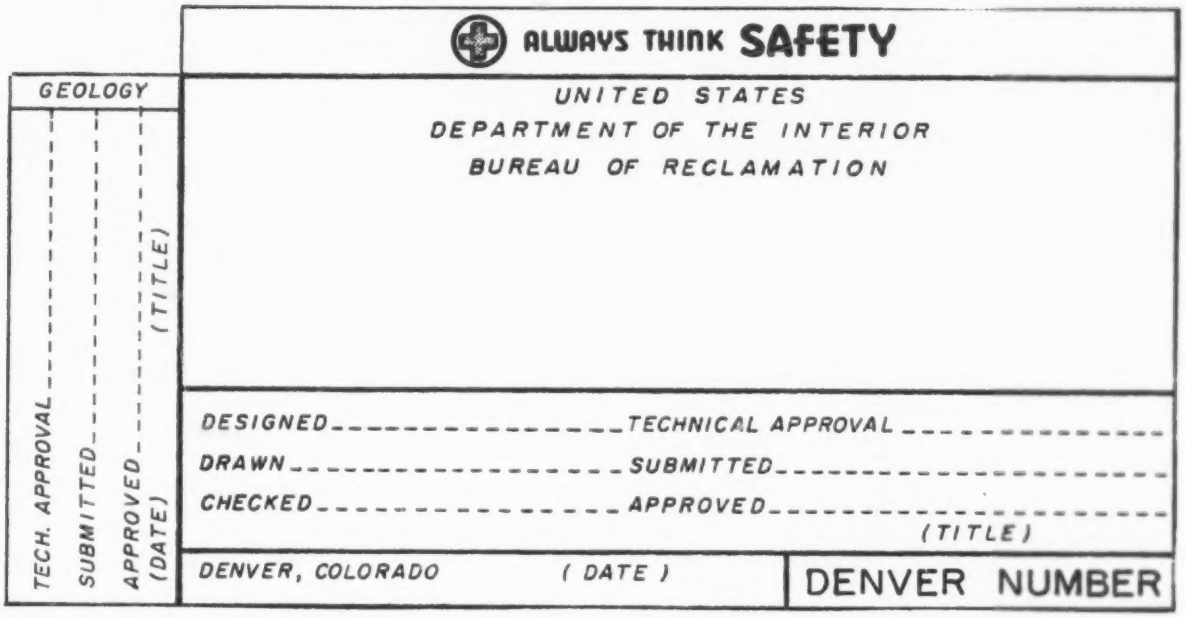


Figure 6. - Signature blocks for Denver engineering drawings with geology prepared by the Division of Geology, E&R Center.

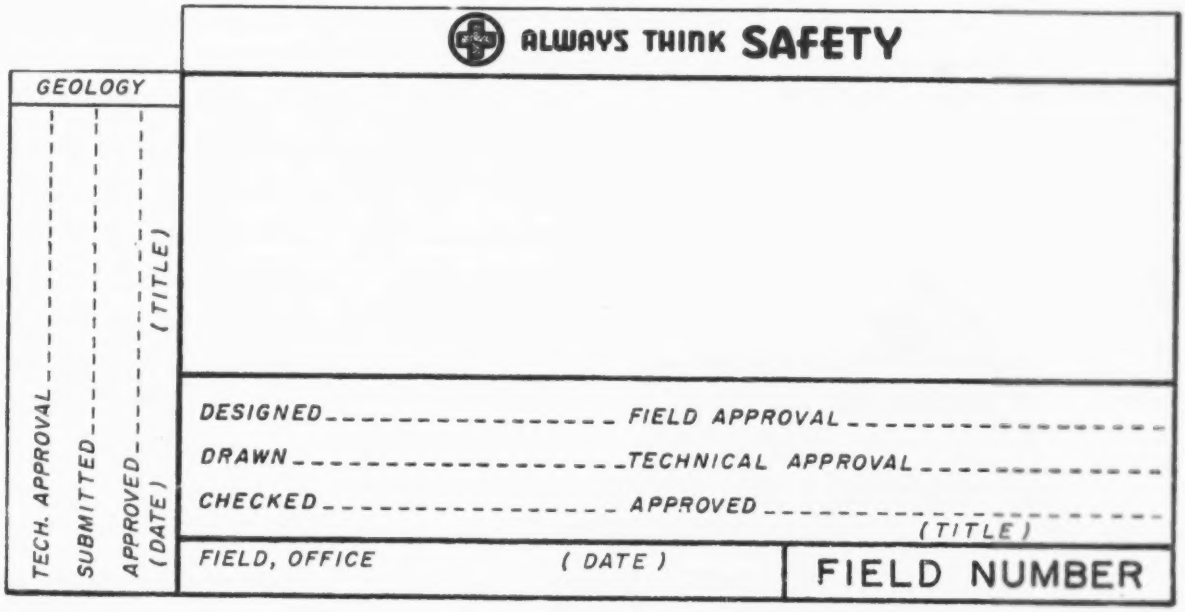


Figure 7. - Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by the Division of Geology, E&R Center.

BEST DOCUMENT AVAILABLE

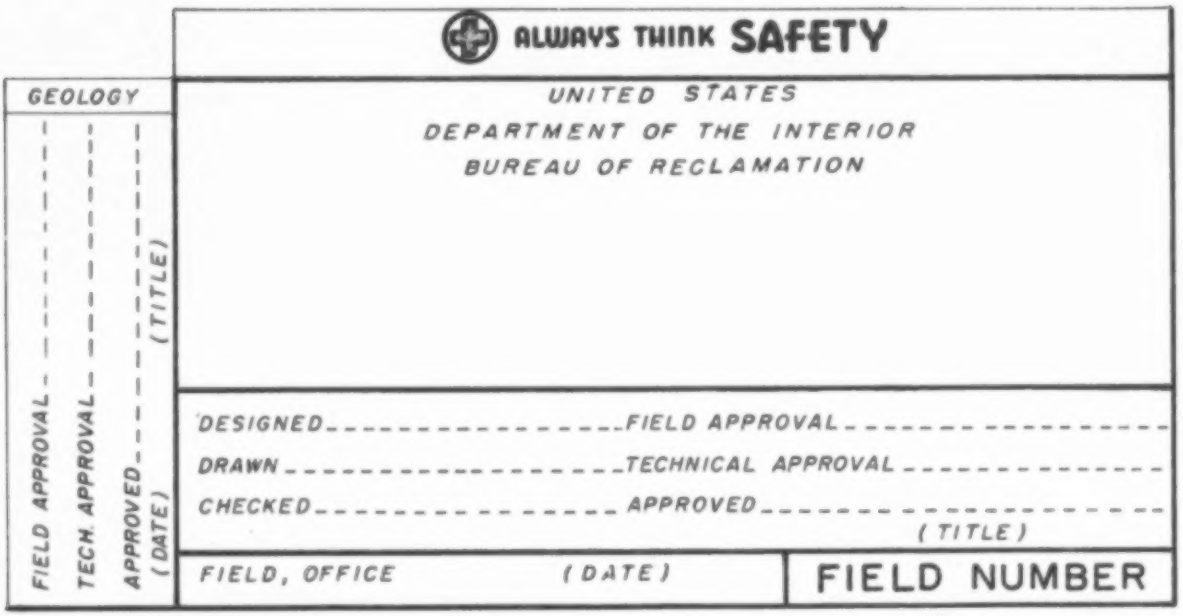


Figure 8. - Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by the regional, project, or field office.

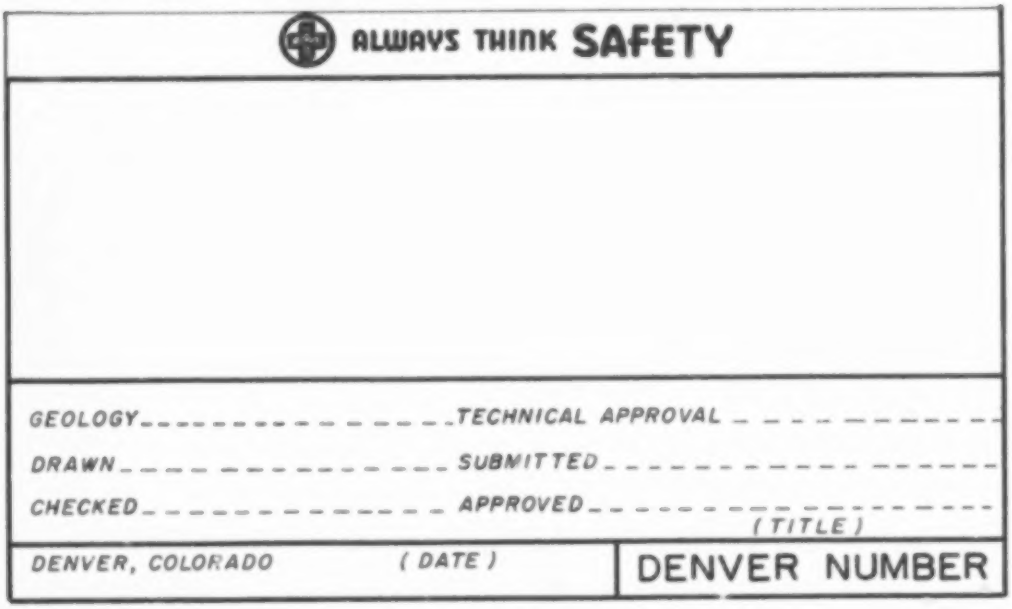


Figure 9. - Signature blocks for geology drawings prepared by the E&R Center.

BEST DOCUMENT AVAILABLE

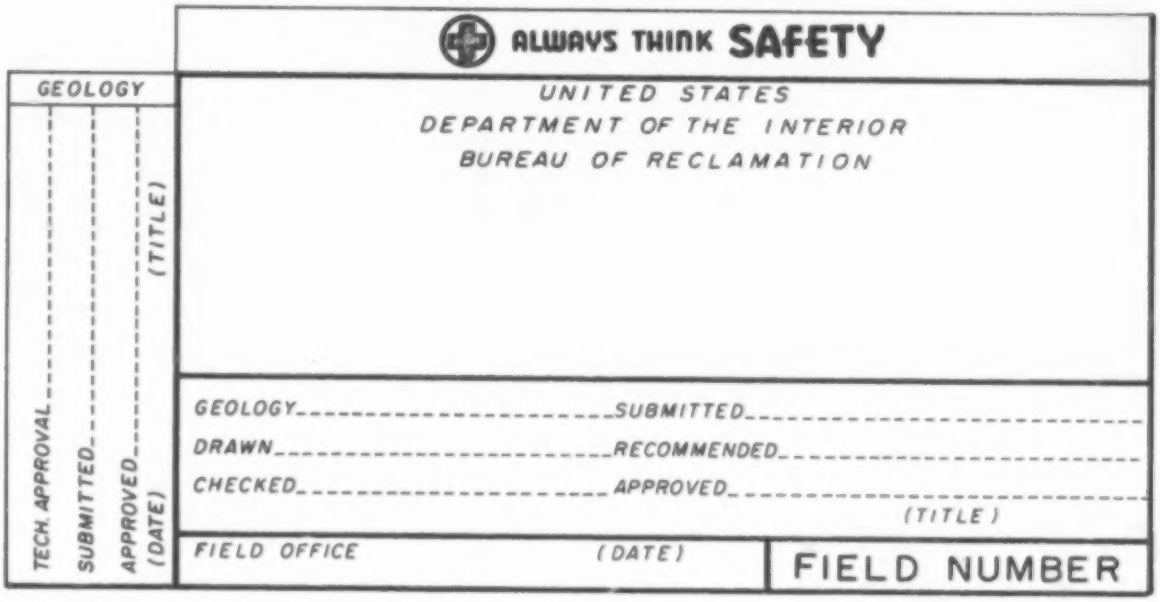


Figure 10. - Signature blocks for geology drawings prepared by field offices.

SECTION 11
USE OF UNIFIED SOIL CLASSIFICATION SYSTEM FOR
GEOLOGIC EXPLORATION

General

All Bureau of Reclamation subsurface investigations of soils for construction or engineering purposes using test pits, trenches, auger holes, drill holes, or other exploratory methods shall be logged and described using the Unified Soil Classification System in accordance with the established guidelines presented in this section.

All investigations associated with land classification for suitability for irrigation, as well as data collection and analyses of soil and substratum materials related to drainage investigations, shall be logged and described using the U.S. Department of Agriculture terminology outlined in Appendix I to Agriculture Handbook No. 436 (Soil Taxonomy) dated December 1975.

Use of SI Units

1. All soil classification descriptions are to be in SI (metric) units.

   a. For metric specifications, Form 7M-1336 (4-77), "Log of Test Pit or Auger Hole," is available. All information requested on the form is to be in SI units (see example page 11-24).

   b. For specifications using inch-pound units, Form 7-1336 will continue to be used with inch-pound units except that the written soil description will use SI units. The only change will be in the description of particle sizes, mm (millimeters) instead of inches (see example page 11-22).

c. Example word descriptions are shown in examples on pages 11-22 through 11-29. Some examples are presented in the SI format while others are in the inch-pound unit format.

2. For reporting maximum particle size, use:

Fine sand
Medium sand
Coarse sand
5-mm increments from 5 mm to 50 mm
25-mm increments from 50 mm to 300 mm
100-mm increments over 300 mm

for example: "maximum particle size 35 mm"
"maximum particle size 400 mm"

3. For accuracy in measuring and reporting of other data in SI units, see notes on bottom of form 7M-1336.

Changes to notes: 1/ Report to nearest 0.1 m not 0.01 m
6/ Report to nearest 1% not 0.1%

Graphic Symbols

Discontinue use of graphic symbols on Form 7-1336, "Log of Test Pit or Auger Hole."

Descriptive Information Criteria

Dilatancy (reaction to shaking)

None - water condition does not change
*Very slow - water appears and disappears very slowly

---

* Change from Earth Manual.

*Slow - water appears and disappears at a moderate rate
Quick - water appears and disappears rapidly

Dry Strength (crumbles into a powder)

None - crumbles with handling
Low - crumbles with little pressure
Medium - crumbles with considerable pressure
High - will not crumble, may break into pieces
*Very High - will not break, even between finger and hard surface

Toughness and Plasticity

Toughness - consistency near plastic limit
- indicated by pressure required to roll thread, stiffness of thread and lump

**Low - only slight pressure required to roll thread
- weak and soft thread and lump

Medium - medium pressure required to roll thread when approaching plastic limit
- medium stiff thread and lump

High - high pressure required to roll thread when approaching plastic limit
- very stiff thread and lump

Plasticity - ability to deform without cracking, range of plastic state, cohesiveness

---

* Change from Earth Manual.
** Change from Earth Manual; also, do not use "No toughness."

- indicated by ability to roll 3-mm thread, time required to roll thread, number of times thread can be rerolled, stickiness

None - thread cannot be rolled at any water content (nonplastic)

Low - thread can barely be rolled, lump cannot be formed when drier than plastic limit

Medium - thread easy to roll, soil dries moderately fast when worked
- thread cannot be rerolled close to plastic limit
- lump crumbles when drier than plastic limit
- sticky

High - takes considerable time rolling and kneading to reach plastic limit
- lump can be formed without crumbling when drier than plastic limit
- thread can be rerolled several times when close to plastic limit
- very sticky

Moisture

Dry - well below optimum moisture, absence of moisture

Moist - near optimum moisture for fine-grained material, damp but no visible water for coarse-grained material

Wet - well above optimum for fine-grained materials, visible water for coarse-grained material

*Very Wet - free water drains from sample or all voids apparently filled with water; generally from below the water table

Color

Describe color, in basic terms, of wet sample. Use one basic color, if possible. Note presence of mottling or banding.

Odor (warm a moist sample if necessary)

None - no organic odor
Organic - distinctive decaying vegetation smell

Reaction with HCl (use 3:1 water to acid ratio)

None
Weak
Moderate
Strong

Description of Particle Sizes

Descriptive term	Size	Familiar example within the size range
Boulder	300 mm or more	Larger than basketball
Cobble	300 mm to 75 mm	Grapefruit - orange - volleyball
Coarse gravel	75 mm to 20 mm	Tennis ball - grape
Fine gravel	20 mm to No. 4 sieve (5 mm)	Pea
Coarse sand	No. 4 sieve to No. 10 sieve	Ice cream salt
Medium sand	No. 10 sieve to No. 40 sieve	Openings in window screen
Fine sand	No. 40 sieve to No. 200 sieve	Sugar - table salt

* Change from Earth Manual.

BEST DOCUMENT AVAILABLE

Determining Maximum Particle Size

Sand sizes - use coarse, medium, fine

Gravel, cobble, boulders - relate maximum particle size to the sieve opening that the particle would pass, may not be a measured dimension for irregular shaped particles (could pass in diagonal direction of sieve)

Description of Particle Angularity

Rounded, subrounded, subangular, angular

Description of Particle Shape (see page 11-37)

Flat - width to thickness ratio 3 or more
Elongated - length to width ratio 3 or more
Flat and elongated - meets criteria for both flat and elongated

Organic Soils (Pt, OL, and OH)

Organic material has no specific grain size. Particle sizes may range from colloidal-size to fibrous pieces several millimeters in length. Its presence is determined by feel, color, and odor.

Peat (Pt) - Soils with more than 50 percent organic matter. Usually very dark to black in color with strong organic odor. Original plant forms may or may not be readily recognized. In general, the greater the organic content the greater the water content, void ratio, and compressibility of the peat.

Organic Silts and Clays (OL and OH) - Soils (below "A" line) basically composed of mineral constituents but with enough organic matter to

avoid using as a foundation or construction material. Presence of organic material (color, odor, feel) may or may not be readily recognized.

Laboratory criteria - A reduction in liquid limit after oven drying to a value less than 75 percent of the liquid limit before oven drying.

Visual-manual test criteria:

undisturbed sample - acts as a sponge; free water can be squeezed out

remolded sample - the thread at the plastic limit is weak and spongy

Undisturbed (In-place) Conditions

Consistency (fine-grained soils)

Very soft - thumb penetrates soil more than 25 mm
Soft - thumb penetrates soil about 25 mm
Firm - thumb indention up to 5 mm
Hard - no indention with thumb, readily indented with thumbnail
Very hard - not indented with thumbnail

Degree of Compactness (coarse-grained soils)

Loose - high amount of voids; settlement on jarring
Dense - no displacement on jarring

*Structure (for description of soils only)

Stratified - alternating layers of varying material or color

**Laminated - alternating layers of varying material or color with layers less than 6-mm thick

**Fissured - breaks along definite planes of fracture with little resistance to fracturing

**Slickensided - fracture planes appear polished or glossy, sometimes striated

**Blocky - cohesive soil that can be broken down into small angular lumps which resist further breakdown

Lensed - inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay

Homogeneous - same color and appearance throughout

Heterogenous - mixture of soil types not in layers or lenses

Special Structural Characteristics

Root holes - holes remaining after roots have decayed

Moisture, Colors, Odor, Reaction with HCl

Same as disturbed samples

---

* Note: Structure descriptions for soils are not synonymous with descriptions for bedrock properties.
** Do not use for coarse-grained soils (except fine sands can be laminated).

Cementation (coarse-grained soils only)

Weak	- crumbles or breaks with handling or little pressure
Moderate	- crumbles or breaks with considerable pressure
Strong	- will not crumble or break with finger pressure

If the logger is not a geologist and there is a question as to whether a material should be described as strongly cemented soil or as sandstone or other rock designation, consult a geologist. A geologist should also be consulted on fine-grained soils if there is a question as to whether it should be described as a soil or as siltstone, claystone, or shale.

Typical Names

Clean Coarse-grained Soils

GW - WELL GRADED GRAVEL
GP - POORLY GRADED GRAVEL
SW - WELL GRADED SAND
SP - POORLY GRADED SAND

Fine-grained Soils

ML - SILT
SANDY SILT
GRAVELLY SILT
CL - LEAN CLAY
SANDY CLAY
GRAVELLY CLAY
MH - ELASTIC SILT
SANDY SILT
GRAVELLY SILT

CH - FAT CLAY
SANDY CLAY
GRAVELLY CLAY

SANDY SILT OR SANDY CLAY - More than 25-percent coarse-grained particles, predominantly sand

GRAVELLY SILT OR GRAVELLY CLAY - More than 25-percent coarse-grained particles, predominantly gravel

Coarse-grained Soils with Fines

GM - SILTY GRAVEL
GC - CLAYEY GRAVEL
SM - SILTY SAND
SC - CLAYEY SAND

Borderline Classifications*

Use Typical Name of First Symbol:

GW-SW - WELL GRADED GRAVEL
SW-SM - WELL GRADED SAND
GC-SC - CLAYEY GRAVEL
SC-CL - CLAYEY SAND
ML-MH - SILT
MH-ML - ELASTIC SILT

Except for:

CL-CH - LEAN TO FAT CLAY
CL-ML - SILTY CLAY
ML-CL - CLAYEY SILT
CL-SC - SANDY CLAY

*Used as examples only, not a complete list.

Organic soils

OL - ORGANIC SILT
OH - ORGANIC CLAY
Pt - PEAT

Use of the Unified Soil Classification System as a Secondary Identification Method for Materials Other Than Natural Soils

General

The following materials are not considered as natural soils and should not be given a primary USCS classification:

Partially lithified or poorly cemented materials

Shale	Claystone
Sandstone	Siltstone

Processed, manmade, or other materials

Crushed rock	Slag
Crushed sandstone	Shells

Description format and classification for these materials are discussed individually in the following paragraphs.

Partially Lithified or Poorly Cemented Materials

For the partially lithified or poorly cemented materials, it is sometimes necessary to classify the material according to the USCS because the material will be excavated, processed, or manipulated for use as a construction material. When the physical properties are to be determined for these materials for classification, the material must be processed by grinding or slaking in water into a soil.

The physical properties and resulting classification describe the soil type as created by the reworking of the original material. The USCS classification can then be used as a secondary identification. However, the classification symbol and typical name must be reported within quotation marks on any logs, tables, figures, and in reports. If laboratory tests are performed on these materials, the results must be reported as shown in table 11-1.

An example of a written narrative for test pit and auger hole logs for visual classification is as follows:

Symbol	Description
SHALE CHUNKS	3.4 to 7.8 ft. SHALE CHUNKS - retrieved as 2- to 4-in pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 hours, material classified as "SANDY CLAY (CL)" - Approx. 60% fines with high plasticity, high dry strength, no dilatancy and high toughness; approx. 35% fine to medium, hard sand; approx. 5% gravel-size pieces of shale.

Processed or Manmade Materials

The processed, manmade, or other materials are also often used as construction materials, and the USCS classificaion can be used as a secondary identification. The typical name and classification symbol are to be within quotation marks. If laboratory tests are performed on these materials, the results must be reported as shown in table 11-1.

7M-1783 (10-76)
Bureau of Reclamation

Table 11-1 - Examples of Unified Soil Classification System as a Secondary Identification.

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS (Inplace Density)

SI METRIC

TABLE 11-1

PROJECT _____ FEATURE _____

SHEET 1 OF 1

IDENTIFICATION				PARTICLE-SIZE FRACTIONS IN PERCENT						CONSISTENCY LIMITS			SPECIFIC GRAVITY				INPLACE DENSITY			
				FINES										PLUS NO. 4						
SAMPLE NUMBER 59S-	HOLE NUMBER	DEPTH - m	CLASSIFICATION SYMBOL	SMALLER THAN 0.005 mm	0.005 TO 0.074 mm	SAND NO. 200 (0.074 mm) TO NO. 4 (4.75 mm)	GRAVEL NO. 4 (4.75 mm) TO 76.2 mm	COBBLES 3 76.2 mm TO 127 mm	OVERSIZE LARGER THAN 127 mm	LIQUID LIMIT - %	PLASTICITY INDEX - %	SHRINKAGE LIMIT - %	MINUS NO. 4	BULK	APPARENT	ABSORPTION - %	DRY DENSITY - kg/m^3	WATER CONTENT - %	DEGREE OF SATURATION - %	
	Example 1																			
12	AP-13	4.7-6.2	shale chunks			(as received)														
		*	"CL"	53	30	17														
	Example 2																			
13	DH 313-B	27.2-28.7	siltstone			(as received)											118	18	17	19
		*	"ML"	50	41	9				27	3									
	Example 3																			
14	Commercial Source		Crushed Sandstone (as received)																	
			"SP-SM"	5	4	91				22	2									
	Example 4																			
15	DH No. 3		Crushed Rock																	
			"GP"	0	0	11	89													
	Example 5																			
16	Waste Pile 7B		Slag																	
	CF and I		"GP"	2	1	25	72													

* properties of material after processing in laboratory

NOTE: *Numbers in parentheses are metric equivalents of numbers directly above.*

TABLE 11-1 SHEET 1 OF 1

BEST DOCUMENT AVAILABLE

An example of a written narrative for logs for visual classification is as follows:

Symbol	Description
CRUSHED ROCK	Stockpile No. 3 CRUSHED ROCK - processed gravel and cobbles from P.T. No. 7; "POORLY GRADED GRAVEL (GP)" - approx. 90% fine hard, angular gravel-size particles; approx. 10% coarse, angular sand-size particles; dry, tan, no reaction with HCl.

Special Cases For USCS Classification

Some material that requires a classification and description according to the USCS should not have a heading that is a classification typical name. When these materials will be used in, or influence, design and construction, they should be described according to the criteria for logs of test pits and auger holes and the classification symbol and typical name placed in quotation marks similar to the discussion on "Use of the Unified Soil Classification System as a Secondary Identification Method for Materials Other Than Natural Soils." The heading should be as follows:

Topsoil
Drill Pad Fill
Gravel Road Surfacing
Mine Tailings
Uncompacted Fill or Fill

For example:

Classification Symbol	Description
TOPSOIL	0.0 - 2.6 ft. TOPSOIL - would be classified as "ORGANIC SILT (OL)." Approx. 80% fines with low plasticity, slow dilatancy, low dry strength, and low toughness; approx. 20% fine to medium sand; wet, dark brown, organic odor, weak reaction with HCl; roots present throughout.

Some material should be described but not given a classification symbol or typical name, such as landfill (trash, garbage, etc.) or asphalt road.

All of the above listed terms are only examples; this is not a complete list.

If the above materials are not to be used or influence design or construction, only the basic term as listed above may be shown on the logs without a compete description or classification.

Format of Word Descriptions for Test Pits and Auger Hole Logs

General

1. Capitalize typical name. If cobbles and boulders are present, include in typical name (see example page 11-27).

2. List percentages of fines, sand, gravel in descending order of percent (must add up to 100 percent). Estimate percentages to closest 5 percent. If a component is present but is less than 5 percent of the total, use "trace" for 1 to 3 percent. "Trace" is not included in the 100 percent.

3. Use "approx." not "about."

4. Describe plasticity of fines as:

"approx. 30% fines with high plasticity"
"approx. 60% fines with low to medium plasticity"
"approx. 10% nonplastic fines"

5. Give results of hand tests when performed.

6. Use "reaction with HCl."

7. Do not give unnecessary information:

"no toughness" "no odor"
"no gravel" "no fines"

A result of a hand test is positive information:

"no dilatancy" "nonplastic"
"no dry strength" "no reaction with HCl"

Undisturbed (In-place) Conditions

1. List in-place conditions in separate paragraph (see example page 11-26).

2. Give geologic interpretation in separate paragraph (see example page 11-26). Do not give geologic interpretation for earth dam borrow areas; however, factual geologic data may be presented.

3. Interpretation of the geologic origin of borrow materials may be included in the narrative section of the materials portion of the design data submittals. Geologic interpretations should be made by or under the supervision of a geologist.

Auger Holes

1. Do not give in-place soil conditions (consistency, compactness) on auger hole logs (unless the holes are large enough to inspect). Instead, describe difficulty of augering (see example page 11-24). Also describe caving or any other unusual occurrence during drilling of the auger hole.

Format of Word Descriptions on Test Pit and Auger Hole Logs for Soils with Cobbles and Boulders

1. If soil has less than 50 percent cobbles and boulders (by volume), give typical name of minus 75-mm portion and include cobbles and/or boulders in typical name (see example page 11-27). Use two paragraphs to describe soil (see examples pages 11-27 and 11-28).

   a. Describe minus 75-mm fraction in first paragraph. Percentages are estimated by weight.

   b. Describe total sample in second paragraph. Percentages are estimated by volume. If percent of cobbles and boulders are determined by measurement, still use approx. in the word description.

2. If soil has more than 50 percent cobbles and boulders (by volume), list cobbles and boulders first in typical name (see example page 11-29). Do not give a classification symbol.

   a. Describe total sample in first paragraph. Percentages are estimated by volume.

   b. Describe minus 75-mm fraction in second paragraph. Percentages are estimated by weight.

*3. Angular particles above 75 mm in size are to be described as cobbles and boulders not as rock fragments. Describe shape in word description.

---

* Change from Earth Manual.

Format of Word Descriptions for Drill Hole Logs

General

The description of surficial deposits and soil-like materials in geologic logs of exploration holes generally referred to as drill holes, such as core holes, standard penetration test holes, drive-tube holes, Denison holes, or other sampling holes where cores or samples of soils are obtained, shall be logged using similar descriptive criteria and format established for test pits and auger holes except as noted in the following paragraphs.

Geologic Interpretation

Unlike test pit logs where geologic interpretations may be provided at the bottom of the log form, geologic interpretations are required on drill hole logs. The geologic classification (i.e., Quaternary Alluvium, Quaternary Glacial Outwash, Quaternary Landslide, Tertiary Basin Fill Deposits) shall be provided as main headings on the geologic drill hole log.

Exceptions to Test Pit and Auger Hole Format and Descriptions for Drill Hole Logs

USCS typical names are to be capitalized in all test pit and auger hole logs. Where capitalization of the USCS typical name would conflict with main headings, only the first letter of each word in the typical name and the letters in the typical name symbol (GP) need be capitalized. If the first letter of each word is not capitalized, the name is considered informal usage only, and not a USCS classification.

Classification and word description format for drill hole logs is similar to those used for test pit logs. Materials recovered from drill holes are generally considered to represent in-place conditions.

Exceptions to these criteria are where samples are not recovered or where poor recovery precludes classification.

Samples Recovered From Wash Borings or as Cuttings - Where drill holes are advanced with a rock bit, water jet, or other nonsampling methods, a USCS typical name or classification of the recovered materials should not be assigned, nor should in-place USCS descriptions, such as consistency and compactness, be used. However, descriptive criteria such as particle size, dry strength, and reaction to HCl should be provided using the same terminology and format used for auger holes. Descriptions should be preceded by "Recovered cuttings as * * *" or "Recovered wash samples as * * *" (see example, 0.0 - 11.7 ft interval, page 11-30).

Poor or partial recovery - Where poor or partial recovery precludes accurate classification, a primary USCS classification should not be assigned, but as much descriptive information as possible shall be provided. Recovered materials, together with known drilling conditions, cuttings, and drilling fluid colors or losses may be used to interpret reasons for losses and types of materials lost. However, an appropriate subheading (i.e., "Poor Recovery") should be used (see examples, pages 11-30 and 11-31).

Materials Other than Soils and Special Cases

As discussed in previous subjections "Use of the Unified Soil Classification System as a Secondary Identification Method for Materials Other Than Soils" and "Special Cases for USCS Classification," exceptions to the test pit and auger hole classification and format are also applicable to drill hole logs. These special cases include processed or manmade materials, shells, partially lithified or poorly cemented materials and decomposed bedrock, and shallow surficial deposits or soils. In addition to these special cases, for purposes of drill hole logging, there are two other special categories where soil-like materials are not classified by the

Unified Soil Classification System. These are slide-failure zones or planes, shear or fault zones, and interbeds recovered as soil-like material; and, landslides and talus.

Format and classification for these exceptions are described below:

Processed or manmade materials. - Surficial deposits such as tailings, crushed rock, shells, or slag shall be assigned a genetic name such as filter, bedding, or drain material, shells, tailings, and road base, and a USCS classification and typical name are assigned in quotation marks, for example: Filter material, "poorly graded sand (SP-SM)." Soil descriptors are then used to describe the materials.

Where drill holes penetrate embankment materials, main headings on the drill hole logs should be a classification of the type of embankment, such as "Zone 3 Miscellaneous Embankment." The materials recovered are classified and typical names are provided as subheadings. See 1.0- to 3.9-ft and 3.9- to 15.4-ft intervals shown in the example on page 11-31.

Partially lithified or poorly cemented materials and decomposed bedrock - Descriptions of partially lithified or poorly cemented materials such as siltstone, claystone, sandstone, and shale, or decomposed bedrock which are disaggregated during drilling or field classification testing shall be classified by geologic formation name, if known, or by an appropriate rocktype name of the in situ materials and described as bedrock. A USCS classification for the disaggregated materials should be reported in quotation marks on the drill logs and all figures, tables, drawings, or narrative descriptions. The disaggregation mechanism (i.e., drilling or testing) shall be specified (see example, 17.3- to 67.9-ft interval, page 11-33).

Shallow surficial deposits. - Surficial deposits such as drill pad or dozer trench fill for drill setups, shallow slope wash, or

topsoil materials which will not be used in, or influence design or construction, may be classified by genetic classification (i.e., "fill," "slope wash," or "topsoil.") Complete USCS descriptions are not required on drill hole logs; however, a USCS classification may be assigned. Although a complete description is not required on each log, an adequate description of these materials shall be provided on the general legend, explanation, and note drawing and in the narrative of the report.

Slide failure zones or planes, shear or fault zone, and interbeds recovered as soil-like materials. - These features should be described using genetic geologic names. Shear and fault zone descriptors are provided in section 5. Examples of slide failure plane descriptions are provided in the examples on pages 11-32 and 11-33.

Landslides and talus. - Surficial deposits such as landslides and talus shall be assigned their genetic geologic name in the main headings of the drill hole log. Landslide debris composed primarily of soils is classified as landslide in the main heading, and, where differences in materials are present, USCS classifications are provided in the subheadings. The materials are then described using the descriptive criteria for test pit logs (see example on page 11-33). Where materials are predominantly rock fragments, such as talus and block slides, the materials should be logged similar to the example on page 11-32.

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N. _____ Ground Elevation _____ Approx Dimensions _____

Depth to Water Level* _____ Method of Excavation _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL LETTER	CLASSIFICATION SYMBOL GRAPHIC	DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS ## VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH
GW			one 80 lb sack sample	0.0 to 5.2 ft WELL GRADED GRAVEL: approx. 70% coarse to fine, hard, subangular gravel; approx 30% coarse to fine, hard, subangular sand; trace of fines; maximum size, 75 mm; moist, brown; hard to auger; no reaction with HCl		DO NOT GIVE IN-PLACE CONDITIONS ON AUGER HOLES			
		5.2							
SP			two 80 lb sack sample	5.2 to 10.5 ft POORLY GRADED SAND: approx. 95% medium to fine, hard, angular sand; approx. 5% fines; maximum size, medium sand; wet, yellow-brown; hard to auger; weak reaction with HCl					
		10.5							
GP			one 80 lb sack samples	10.5 to 17.6 ft POORLY GRADED GRAVEL: approx. 60% coarse to fine, hard, subangular to subrounded gravel; approx. 40% predominantly fine sand; maximum size, 50 mm; dry, tan; hard to auger; no reaction with HCl					
		17.6		17.6 to 25.3 ft WELL GRADED SAND: approx. 65% coarse to fine, hard, subangular sand; approx. 30% coarse to fine, hard, subrounded gravel; approx. 5% fines; maximum size, 75 mm; very wet, brown; hard to auger; weak reaction with HCl.					
SW			none						
		25.3							

REMARKS

EXAMPLE WORD DESCRIPTIONS: CLEAN COARSE GRAINED SOILS

AUGER HOLE

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
Applicable only to borrow pits and to foundations which are potential sources of construction materials.

(Lbs of rock sampled) 100 / (Bulk specific gravity of rock) 62.4 (Cubic feet of hole sampled)
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N. _____ E _____ Ground Elevation _____ Approx. Dimensions _____

Depth to Water Level* _____ Method of Excavation _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL		DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **				
LETTER	GRAPHIC				VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED LBS	PERCENTAGE BY VOLUME OF 3 TO 5-INCH	WEIGHT OF PLUS 5-INCH SAMPLED LBS	PERCENTAGE BY VOLUME OF PLUS 5-INCH
CL		4.3	two 80 lb sack samples	0.0 to 4.3 ft LEAN CLAY: approx. 90% fines with medium plasticity, high dry strength, medium toughness; approx. 10% predominantly fine sand; maximum size, coarse sand; moist, brown; hard to auger; no reaction with HCl		DO NOT GIVE IN-PLACE CONDITIONS ON AUGER HOLES			
ML		11.0	none	4.3 to 11.0 ft SANDY SILT: approx. 75% nonplastic fines, quick dilatancy, no dry strength; approx. 25% fine sand; maximum size, fine sand; wet, gray, faint organic odor, some roots present; easy to auger; weak reaction with HCl					
CH		17.7	one 80 lb sack sample	5.1 to 17.7 ft FAT CLAY: approx. 90% fines with high plasticity, high to very high dry strength, high toughness; approx. 10% medium to fine sand; trace of gravel; maximum size, 15 mm; dry, reddish-brown; hard to auger; strong reaction with HCl					
MH		25.5	two 80 lb sack samples	17.7 to 25.5 ft ELASTIC SILT: approx. 100% fines with low to medium plasticity, slow dilatancy, medium dry strength, low to medium toughness; trace of fine sand; maximum size, fine sand; very wet, black; easy to auger; weak reaction with HCl					

REMARKS.

EXAMPLE WORD DESCRIPTIONS: FINE GRAINED SOILS

AUGER HOLE

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

** (Lbs of rock sampled) 100 / (Bulk specific gravity of rock) 62.4 (Cubic feet of hole sampled)
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N _____ E _____ Ground Elevation _____ Approx. Dimensions1/ _____

Depth to Water Level1/ & 2/ _____ Method of Excavatir _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL	DEPTH (m)1/	SIZE AND TYPE OF SAMPLE TAKEN3/	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE DESIGNATION E-3, EARTH MANUAL, FOR METHOD OF DESCRIPTION; GIVE GEOLOGIC AND IN PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	VOLUME OF HOLE SAMPLED (m³)5/	PERCENTAGE OF COBBLES AND BOULDERS4/ MASS OF 75 TO 125 mm SAMPLED (kg)3/	% BY VOLUME OF 75 TO 125 mm6/	MASS OF PLUS 125 mm SAMPLED (kg)3/	% BY VOLUME OF PLUS 125 mm6/
SM		one 40 kg sack sample	0.0 to 3.1 m SILTY SAND: approx. 70% coarse to fine, hard, angular sand; approx. 25% nonplastic fines, quick dilatancy, no dry strength; approx. 5% fine, hard, angular gravel; maximum size 15 mm; moist, brown, faint organic odor, some roots present; easy to auger; no reaction with HCl					
	3.1							
GC		one 40 kg sack sample	3.1 to 6.7 m CLAYEY GRAVEL: approx. 75% coarse to fine, hard, subrounded gravel; approx. 15% fines with medium plasticity, high dry strength, medium toughness; approx. 10% coarse, hard, subrounded sand; maximum size 75 mm; dry, brown; hard to auger; strong reaction with HCl					
	6.7							
SC		one 40 kg sack sample	6.7 to 9.8 m CLAYEY SAND: approx. 50% coarse to fine, hard, subangular to subrounded sand; approx. 25% fine, hard, subangular to subrounded gravel; approx. 25% fines with medium plasticity, high dry strength, medium toughness; maximum size 20 mm; wet, reddish-brown; easy to auger; weak reaction with HC					
	9.8							

DO NOT GIVE IN-PLACE CONDITION FOR AUGER HOLE
i.e., consistency
degree of compaction
structure

DO GIVE DIFFICULTY OF AUGERING
i.e., easy to auger
hard to auger

Exception: large diameter bucket auger holes where in-place conditions can be determined

REMARKS:

EXAMPLE WORD DESCRIPTIONS: COARSE GRAINED SOIL WITH FINES

AUGER HOLE

NOTES:
1/Report to nearest 0.01 m 0.1 m
2/Record after water has reached its natural level and give date of reading
3/Report to nearest 0.5 kg
4/Applicable only to borrow pits and to foundations which are potential sources of construction materials

5/Report to nearest 0.001 m³
6/ (1) % = $\frac{\text{(mass of rock sampled)}}{\text{(Bulk density) X (cubic metres of hole sampled)}}$ X 100
(2) Record bulk density in Remarks, stating how obtained (measured or estimated)
Report to nearest 0.1% 1%

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature ..... Project ..... Area Designation .....

Hole No. ..... Coordinates N ..... E ..... Ground Elevation ..... Approx. Dimensions1/ .....

Depth to Water Level1/ & 2/ ..... Method of Excavation ..... Date ..... Logged by .....

CLASSIFICATION SYMBOL	DEPTH (m)1/	SIZE AND TYPE OF SAMPLE TAKEN3/	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE DESIGNATION E 3, EARTH MANUAL, FOR METHOD OF DESCRIPTION; GIVE GEOLOGIC AND IN PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	VOLUME OF HOLE SAMPLED (m³)5/	PERCENTAGE OF COBBLES AND BOULDERS4/ MASS OF 75 TO 125 mm SAMPLED (kg)3/	% BY VOLUME OF 75 TO 125 mm6/	MASS OF PLUS 125 mm SAMPLED (kg)3/	% BY VOLUME OF PLUS 125 mm6/
CL-CH		none	0.0 to 2.9 m LEAN TO FAT CLAY: approx. 95% fines with medium to high plasticity, high dry strength, medium to high toughness; approx. 5% fine sand; maximum size, fine sand; dry, reddish-brown; hard to auger; no reaction with HCl		DO NOT GIVE IN-PLACE CONDITIONS ON AUGER HOLES			
	2.9							
GP-GC		none	2.9 to 7.2 m POORLY GRADED GRAVEL: approx. 60% coarse to fine, hard, subangular gravel; approx. 30% predominantly fine sand; approx. 10% fines with medium plasticity, high dry strength, medium toughness; maximum size, 75 mm; moist, tan; hard to auger; weak reaction with HCl					
	7.2							
SM-ML		none	7.2 to 9.7 m SILTY SAND: approx. 55% medium to fine sand; approx. 45% nonplastic fines, no dry strength; maximum size, medium sand; very wet, reddish-brown; easy to auger; no reaction with HCl					
	9.7							

REMARKS:

EXAMPLE WORD DESCRIPTIONS: BORDERLINE SOILS

AUGER HOLE

NOTES:
1/Report to nearest 0.01 m or 0.1 m
2/Record after water has reached its natural level and give date of reading
3/Report to nearest 0.5 kg
4/Applicable only to borrow pits and to foundations which are potential sources of construction materials

5/Report to nearest 0.001 m³

6/ (1) % = $\frac{\text{(mass of rock sampled)}}{\text{(Bulk density) X (cubic metres of hole sampled)}}$ X 100

(2) Record bulk density in Remarks, stating how obtained (measured or estimated)
Report to nearest 0.1% 1%

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N _____ E _____ Ground Elevation _____ Approx. Dimensions1/ _____

Depth to Water Level1/ & 2/ _____ Method of Excavation _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL	DEPTH (m)1/	SIZE AND TYPE OF SAMPLE TAKEN3/	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE DESIGNATION E-3, EARTH MANUAL, FOR METHOD OF DESCRIPTION; GIVE GEOLOGIC AND IN PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	VOLUME OF HOLE SAMPLED (m³)5/	PERCENTAGE OF COBBLES AND BOULDERS4/			
					MASS OF 75 TO 125 mm SAMPLED (kg)3/	% BY VOLUME OF 75 TO 125 mm6/	MASS OF PLUS 125 mm SAMPLED (kg)3/	% BY VOLUME OF PLUS 125 mm6/
SC		undisturbed block sample	0.0 to 4.2 m CLAYEY SAND: approx. 50% coarse to fine, hard, subangular to subrounded sand; approx. 25% fine, hard, subangular to subrounded gravel; approx. 25% fines with medium plasticity, high dry strength, medium toughness; maximum size 20 mm; weak reaction with HCl IN-PLACE CONDITION: firm, homogeneous except for occasional lenses of clean fine sand 5-mm to 25-mm thick, moist, reddish-brown GEOLOGIC INTERPRETATION: Alluvial fan		DO NOT GIVE GEOLOGIC INTERPRETATION FOR EARTH DAM BORROW AREA			
	4.2							
CL		undisturbed block sample	4.2 to 9.8 m LEAN CLAY: approx. 90% fines with medium plasticity, high dry strength, medium toughness; approx. 10% predominantly fine sand; maximum size, coarse sand; strong reaction with HCl IN-PLACE CONDITION: soft, homogeneous, wet, brown GEOLOGIC INTERPRETATION: Niobrara formation					
	9.8							

REMARKS:

EXAMPLE WORD DESCRIPTION: IN-PLACE CONDITIONS

TEST PIT

NOTES:
1/Report to nearest 0.1 m
2/Record after water has reached its natural level and give date of reading
3/Report to nearest 0.5 kg
4/Applicable only to borrow pits and to foundations which are potential sources of construction materials
5/Report to nearest 0.001 m³
6/ (1) % = $\frac{\text{(mass of rock sampled)}}{\text{(Bulk density) X (cubic metres of hole sampled)}}$ X 100
(2) Record bulk density in Remarks, stating how obtained (measured or estimated)
Report to nearest 1%

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N. _____ E _____ Ground Elevation _____ Approx. Dimensions _____

Depth to Water Level* _____ Method of Excavation _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL		DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION" GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **				
LETTER	GRAPHIC				VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH
GW		7.4	none	0.0 to 7.4 ft WELL GRADED GRAVEL WITH COBBLES AND BOULDERS: approx. 70% coarse to fine, hard, subrounded gravel; approx. 30% coarse to fine, hard, subangular sand; trace of fines TOTAL SAMPLE (BY VOLUME): approx. 22% 75 to 125 mm hard, subrounded cobbles; approx. 14% plus 125 mm hard, rounded cobbles and boulders; remainder minus 75 mm; maximum size 400 mm IN-PLACE CONDITION: loose, heterogenous, dry, brown GEOLOGIC INTERPRETATION: alluvial fan material	444	16410	22	10442	14

REMARKS EXAMPLE WORD DESCRIPTION: (1) SOIL WITH COBBLES AND/OR BOULDERS
(2) MEASURED VOLUME OF PLUS 75 mm

TEST PIT

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{\text{(Lbs of rock sampled) } 100}{\text{(Bulk specific gravity of rock) } 62.4 \text{ (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature ..... Project ..... Area Designation .....
Hole No. ..... Coordinates N ..... E ..... Ground Elevation ..... Approx. Dimensions1/ .....
Depth to Water Level1/ & 2/ ..... Method of Excavation ..... Date ..... Logged by .....

CLASSIFICATION SYMBOL	DEPTH (m)1/	SIZE AND TYPE OF SAMPLE TAKEN3/	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE DESIGNATION E-3, EARTH MANUAL, FOR METHOD OF DESCRIPTION; GIVE GEOLOGIC AND IN PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	VOLUME OF HOLE SAMPLED (m³)5/	PERCENTAGE OF COBBLES AND BOULDERS4/ MASS OF 75 TO 125 mm SAMPLED (kg)3/	% BY VOLUME OF 75 TO 125 mm6/	MASS OF PLUS 125 mm SAMPLED (kg)3/	% BY VOLUME OF PLUS 125 mm6/
SC	2.7	Two 40 kg sack samples	0.0 to 2.7 m CLAYEY SAND WITH COBBLES: approx. 45% coarse to fine, hard, subrounded sand; approx. 35% fines with medium plasticity, medium toughness; approx. 20% coarse to fine, hard, subrounded gravel; moderate reaction with HCl TOTAL SAMPLE (BY VOLUME): approx. 10% hard, subrounded cobbles; remainder minus 75 mm; maximum size 100 mm IN-PLACE CONDITION: firm, homogeneous, moist, gray; some mica present	--		10		0

NOTE: Oversize estimates:
Trace → 1% to 3%
Then estimate to closest 5%

REMARKS: EXAMPLE WORD DESCRIPTION: (1) SOIL WITH COBBLES AND/OR BOULDERS
(2) ESTIMATED VOLUME OF PLUS 75 mm

TEST PIT

NOTES:
1/Report to nearest 0.01 or 0.1 m
2/Record after water has reached its natural level and give date of reading
3/Report to nearest 0.5 kg
4/Applicable only to borrow pits and to foundations which are potential sources of construction materials
5/Report to nearest 0.001 m³
6/ (1) % = $\frac{\text{(mass of rock sampled)}}{\text{(Bulk density) X (cubic metres of hole sampled)}} \times 100$
(2) Record bulk density in Remarks, stating how obtained (measured or estimated)
Report to nearest 0.1% or 1%

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature _____ Project _____ Area Designation _____

Hole No. _____ Coordinates N _____ E _____ Ground Elevation _____ Approx. Dimensions _____

Depth to Water Level* _____ Method of Excavation _____ Date _____ Logged by _____

CLASSIFICATION SYMBOL		DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION") GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS	PERCENTAGE OF COBBLES AND BOULDERS **				
LETTER	GRAPHIC				VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED LBS	PERCENTAGE BY VOLUME OF 3 TO 5-INCH	WEIGHT OF PLUS 5-INCH SAMPLED LBS	PERCENTAGE BY VOLUME OF PLUS 5-INCH
cobbles and boulders		4.5	one 80 lb sack sample	0.0 to 4.5 ft COBBLES AND BOULDERS WITH SILTY GRAVEL: TOTAL SAMPLE (BY VOLUME): approx. 35% 75 mm to 125 mm hard, subrounded cobbles; approx. 30% plus 125 mm hard, subangular to subrounded cobbles and boulders; remainder minus 75 mm; maximum size 600 mm MINUS 75 mm FRACTION (BY WEIGHT): approx. 40% coarse to fine, hard, subrounded gravel; approx. 30% coarse to fine, hard, subrounded sand; approx. 30% nonplastic fines; no reaction with HCl IN-PLACE CONDITION: loose, homogeneous, moist, brown		35			30

REMARKS: EXAMPLE WORD DESCRIPTION: MORE THAN 50% COBBLES AND BOULDERS

TEST PIT
EARTH DAM
BORROW AREA

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** (Lbs of rock sampled) 100 / (Bulk specific gravity of rock) 62.4 (Cubic feet of hole sampled)
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

GEOLOGIC LOG OF DRILL HOLE

SHEET..... OF.....

FEATURE..... PROJECT..... STATE.....

HOLE NO..... LOCATION..... GROUND ELEV. ..... DIP (ANGLE FROM HORIZ.).....

COORDS. N..... E.....

BEGUN..... FINISHED..... DEPTH OF OVERBURDEN ..... TOTAL DEPTH..... BEARING.....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED..... LOGGED BY..... LOG REVIEWED BY.....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Co or Cm)	PERCOLATION TESTS: DEPTH (FEET) TO	PERCOLATION TESTS: LOSS (G.P.M.)	PERCOLATION TESTS: PRESSURE (P.S.I.)	PERCOLATION TESTS: LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
NOTE: Where materials are not recovered from drill hole, but in-place conditions may be determined from other observations, descriptions are permissible in either the right hand column of the log or as a note in the left hand column. NOTE: No USCS classification where rockbitted or wash bored. NOTE: Where poor recovery is obtained do not assign USCS typical name. However, provide as much descriptive information as possible.									10 20 30 40 50			0.0-14.0': FILL. Exposure in road cut 25' to the west of drill hole is Clayey Gravel (GC) with approx. 75% coarse to fine, hard, angular, metamorphic gravel; 15% fines with medium plasticity, high dry strength, medium toughness; 10% coarse, hard, angular sand; max; size 75mm; strong reaction with HCl. In-place condition is firm, moist, reddish-brown. Material is apparently unzoned miscellaneous fill. 0.0-11.7': Rockbitted. Recovered cuttings as angular, metamorphic sand and fine gravel. 11.7-14.0': Poor Recovery. Recovered four angular, gravel-size fragments with reddish-brown sandy clay coatings in upper 1.5'. Fines and sand washed away. Lower 0.8' is lean clay (residual soil). Materials recovered were approx. 85% fines with low to medium plasticity, high dry strength, medium toughness; 15% predominantly fine sand; max. size coarse sand; firm, moist, dark brown, strong reaction with HCl. 14.0-39.8': PRECAMBRIAN GRANITE. [Describe as rock unit.]

GEOLOGIC LOG OF DRILL HOLE

SHEET..... OF.....

FEATURE..... PROJECT..... STATE.....

HOLE NO..... LOCATION..... GROUND ELEV. ..... DIP (ANGLE FROM HORIZ.).....

COORDS. N..... E.....

BEGUN..... FINISHED..... DEPTH OF OVERBURDEN ..... TOTAL DEPTH..... BEARING.....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED..... LOGGED BY..... LOG REVIEWED BY.....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Co, or Cm)	PERCOLATION TESTS: DEPTH (FEET) TO	PERCOLATION TESTS: LOSS (G.P.M.)	PERCOLATION TESTS: PRESSURE (P.S.I.)	PERCOLATION TESTS: LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									10 20 30 40 50			0.0-1.0': ASPHALT AND ROAD SUBBASE. 1.0-3.9': PERVIOUS EMBANKMENT-ZONE 3. 0.0-2.1': Rockbitted. Recovered cuttings as fine to coarse, angular sand and fine gravel-size, angular, metamorphic rock fragments. 2.1-3.9': Poor Recovery. Recovered as gravel-size, hard, angular, metamorphic and granitic rock fragments and gravel, mostly 30-60mm, max. size 75mm; and approx. 5% soft, wet, sandy clay. No reaction to HCl. Most of fines washed away during drilling. 3.9-15.4': IMPERVIOUS EMBANKMENT-ZONE 1. 3.9-12.7': Lean Clay w/Trace of Cobbles (CL). Approx. 80% fines with medium plasticity, high dry strength, medium toughness; approx. 20% fine to coarse subangular sand; trace of hard, subrounded cobbles; max. size 100mm. Firm, homogeneous, moist, light brown. Weak reaction with HCl. 10.8-12.7': Poor Recovery. Fines washed away, barrel blocked. 12.7-15.4': Sandy Clay (CL). Approx. 60% fines with medium plasticity. [Continue with description.] 15.4-91.7': CRETACEOUS PANOCHE GROUP. 15.4-23.2': Sandstone. Gray, fine grained, etc. [Continue description.]

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

GEOLOGIC LOG OF DRILL HOLE

SHEET..... OF.....

FEATURE..... PROJECT..... STATE.....

HOLE NO..... LOCATION..... GROUND ELEV. ..... DIP (ANGLE FROM HORIZ.).....

COORDS. N..... E.....

BEGUN..... FINISHED..... DEPTH OF OVERBURDEN ..... TOTAL DEPTH..... BEARING.....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED..... LOGGED BY..... LOG REVIEWED BY.....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Co, or Cm)	PERCOLATION TESTS: DEPTH (FEET) TO	PERCOLATION TESTS: LOSS (G.P.M.)	PERCOLATION TESTS: PRESSURE (P.S.I.)	PERCOLATION TESTS: LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									10 20 30 40 50			0.0-1.0': SLOPE WASH (Qc). Red-brown, moist, firm, lean to fat clay. Upper 0.2' is dark brown topsoil. Roots extend to 0.8'. 1.0-38.2': QUATERNARY LANDSLIDE (Qls). Poor to moderate recovery. Composed of randomly oriented, moderately weathered, hard, angular hornblende schist blocks and fragments, in an estimated 5-20% matrix of red-brown lean clay. Blocks and fragments recovered in core lengths to 3.2', mostly 0.5'- to 1.2'- lengths. Scattered 0.2-to 0.4'- thick intervals of clay matrix. Where recovered, matrix consist of approx. 85% fines with medium plasticity, high dry strength, medium toughness. 15% fine to coarse, hard, angular to subrounded sand. Matrix is firm, moist, light brown. No reaction to HCl. 36.-38.2': Slide Plane. 1.9' thick, upper contact dips 30°, dip of lower contact unknown. Composed of approx. 70% fines with medium to high plasticity, high dry strength, medium toughness. Moist, firm, red-brown and tan; no reaction to HCl; and 30% subangular to wedge shaped hard 1/8" to 3/8" hornblende schist fragments. Fragments break with light finger pressure. 37.9-38.2': No Recovery, Fines washed away at start of core run.

BEST DOCUMENT AVAILABLE

7-1887 (8-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET..... OF.....

FEATURE..... PROJECT..... STATE.....

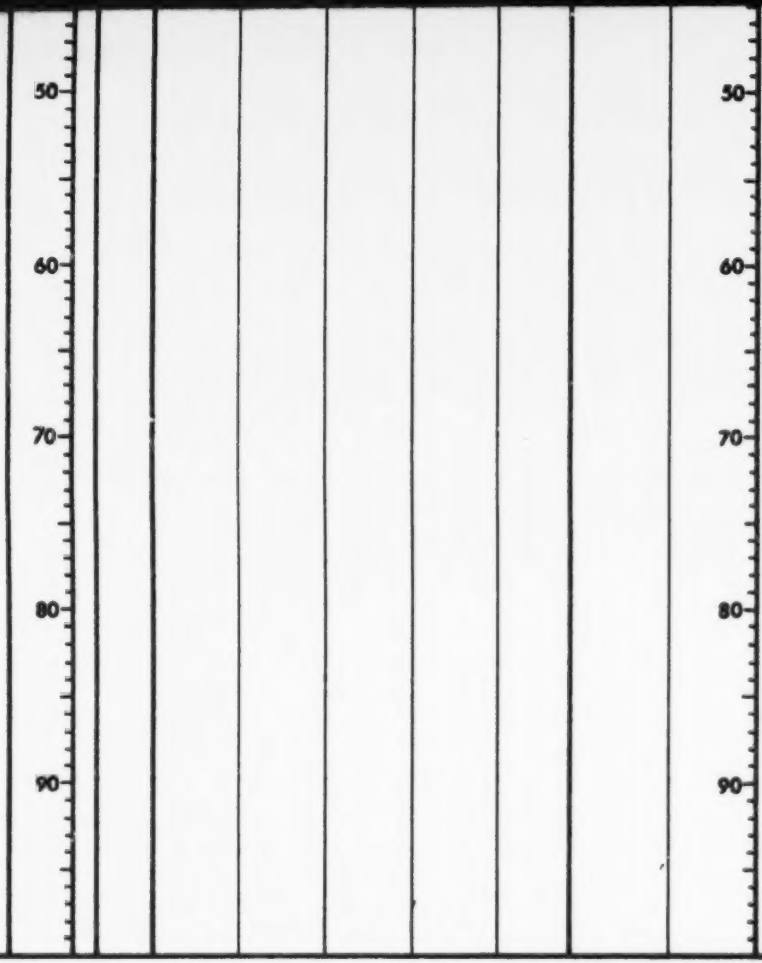
HOLE NO..... LOCATION..... GROUND ELEV. ..... DIP (ANGLE FROM HORIZ.).....
COORDS. N..... E.....

BEGUN..... FINISHED..... DEPTH OF OVERBURDEN ..... TOTAL DEPTH..... BEARING.....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED..... LOGGED BY..... LOG REVIEWED BY.....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	PERCOLATION TESTS: DEPTH (FEET) TO	PERCOLATION TESTS: LOSS (G.P.M.)	PERCOLATION TESTS: PRESSURE (P.S.I.)	PERCOLATION TESTS: LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									10 20 30 40			0.0-2.0': QUATERNARY COLLUVIUM (Qc). Residual soil and slope wash. Consists of approx. 75% red-brown fat clay (with 20% fine sand) and 25% intensely weathered, 0.1 to 0.4' soft, angular, sandstone fragments. 2.0-17.3': QUATERNARY LANDSLIDE DEBRIS. (Qls). Mod. recovery due to gravel-, cobble-, and boulder-size fragments. 2.0-13.6': Sandy Clay with Cobbles (CL). [Describe as per criteria for test pits and auger holes.] 13.6-16.7': Clayey Gravel with Cobbles and Boulders (GC). [Describe as per criteria for test pits and auger holes.] 16.7-17.3': Slide Plane. 0.6' thick, dips 30°, parallel to bedding. Consists of approx. 40% fines with medium plasticity, high dry strength, medium toughness, moist, firm, red-brown; 20% fine angular sand; 45% mostly 1/8" to 3/4" platy to angular, intensely weathered, metashale fragments, max. size 2". Fragments break with light manual pressure.

114



17.1-17.3': Dark brown, highly slickensided surfaces, slickensides parallel to contact.

17.3-152.6': CRETACEOUS PANOCHE GROUP.

17.3-67.9': Sandstone. Fine to medium grained, mostly subangular grains of quartz with trace of mica. Thinly bedded: bedding planes mostly 0.6 to 1.0'; dip 30-35°. Intensely Weathered, body of rock stained light brown, locally light gray. Core can be gouged with moderate knife pressure, breaks across bedding and along grains with light mannual pressure. Moderately Fractured (80% bedding; 20% joints) except as noted below. Core recovered in lengths to 1.1', mostly 0.5 to 0.9'. One joint set noted: (1) dips 60 to 75°, normal to bedding; spaced 1.0-1.5'; joint surfaces smooth, filled with 1/16 to 1/8" red-brown, fat clay. Sandstone can be disaggregated by hand to "clayey sand (SC)."

24.3-31.3': Intensely Fractured.

[Continue with description of rock units.]

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole	D = Diamond, H = Hoystellite, S = Shot, C = Churn			
Hole sealed	P = Packer, Cm = Cemented, Ce = Bottom of casing			
Approx. size of hole (X-series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8",	Nx = 3"
Approx. size of core (X-series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8",	Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8",	Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8",	Nx = 3"

FEATURE ..... PROJECT ..... STATE ..... SHEET .... OF .... HOLE NO. .....

114A

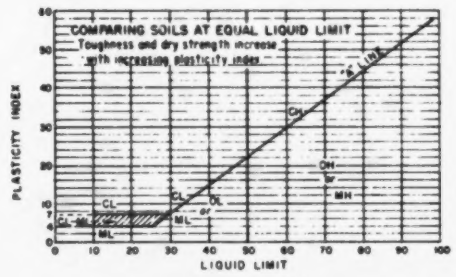
BEST DOCUMENT AVAILABLE

UNIFIED SOIL CLASSIFICATION CHART

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 75 mm and basing fractions on estimated weights)				GROUP SYMBOLS [1]	TYPICAL NAMES	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS — More than half of material is larger than No. 200 (75 μm) sieve size [2] — (For visual classifications, 5 mm may be used as equivalent to the No. 4 (4.75 mm) sieve size.)	GRAVELS — More than half of coarse fraction is larger than No. 4 (4.75 mm) sieve size.	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 (75 μm) sieve size) coarse grained soils are classified as follows:- Less than 5% — GW, GP, SW, SP. More than 12% — GM, GC, SM, SC. 5% to 12% — Borderline cases requiring use of dual symbols.
			Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.	
			Plastic fines (for identification procedures see CL below).	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.	
	SANDS — More than half of coarse fraction is smaller than No. 4 (4.75 mm) sieve size.	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	SW	Well graded sands, gravelly sands; little or no fines.	
			Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands; little or no fines.	
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	SM	Silty sands, poorly graded sand-silt mixtures.	
			Plastic fines (for identification procedures see CL below).	SC	Clayey sands, poorly graded sand-clay mixtures.	
FINE GRAINED SOILS — More than half of material is smaller than No. 200 (75 μm) sieve size. (The No. 200 (75 μm) sieve size is about the smallest particle visible to the naked eye)	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 (425 μm) SIEVE SIZE	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)		
	SILTS AND CLAYS — Liquid limit less than 50	None to low	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with low plasticity.
		Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Low to medium	Slow	Low	OL	Organic silts and organic silt-clays of low plasticity.
	SILTS AND CLAYS — Liquid limit greater than 50	Low to medium	Slow to none	Low to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to high	None to very slow	Low to medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS		Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other highly organic soils.

Use grain size curve in identifying the fractions as given under field identification

$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	Not meeting all gradation requirements for GW
Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	
$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	Not meeting all gradation requirements for SW
Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	



PLASTICITY CHART
FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

[1] Boundary classifications:-Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder

[2] All sieve sizes on this chart are USA Standard Sieves in accordance with ASTM designation E-11.

(FIELD IDENTIFICATION PROCEDURES FOR FINE GRAINED SOILS OR FRACTIONS)

These procedures are to be performed on the minus No. 40 (425 μm) sieve size particles. For field classification purposes, screening is not intended; simply remove by hand the coarse particles that interfere with the tests.

DILATANCY (Reaction to shaking)

After removing particles larger than No. 40 (425 μm) sieve size, prepare a ball of moist soil about 15mm in diameter. Add enough water if necessary to make the soil soft but not sticky.

Place the ball in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the ball which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the ball stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

DRY STRENGTH (Crushing characteristics)

If a crumb of dry soil is not available, after removing particles larger than No. 40 (425 μm) sieve size, mold a ball of soil about 5 mm in diameter to the consistency of putty, adding water if necessary. Allow the ball to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very low dry strength. Silty fine sands and silts have about the same low dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No. 40 (425 μm) sieve size, a ball of soil about 15 mm in diameter is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about 3 mm in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced, and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

(JULY 21,1977) 4103-D-574

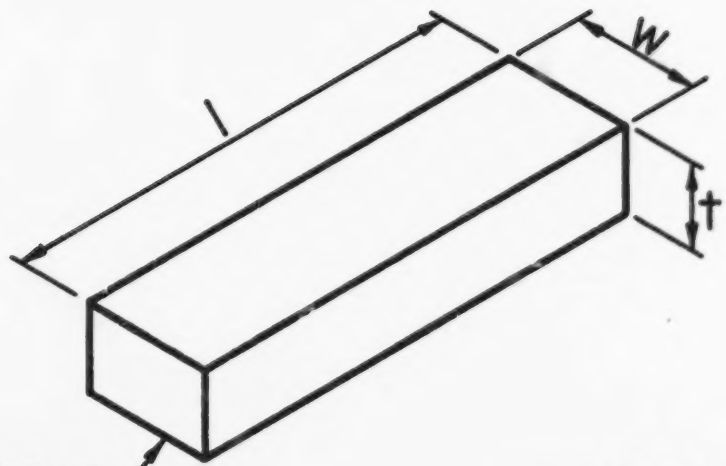
PARTICLE SHAPE

FLAT

$w/t > 3$

ELONGATED

$l/w > 3$



SOIL PARTICLE

w – WIDTH

t – THICKNESS

l – LENGTH

SECTION 12

STANDARDS FOR CARE, RETENTION, AND DISPOSAL OF DRILL CORE AND SUBSURFACE SOIL AND ROCK SAMPLES

General

The procedures and criteria outlined below will be used to determine the care, retention, and disposal of drill core and samples secured in explorations during the investigations for design and construction of Bureau structures.

These instructions apply to all foundation explorations for structures, such as dams, canals, tunnels, power and pumping plants, etc., and construction materials investigations including riprap and borrow. Samples secured in investigations for concrete aggregate, pozzolan, land classification, and drainage (except for drainage structures) are excluded.

These standards are intended to minimize storage costs, meet minimum technical requirements, and avoid unnecessarily long storage periods. Occasions may occur, however, in which their application would result in unnecessary handling or excessive costs. In such cases, the Regional Director should arrange handling appropriate to the special conditions, provided no damage or deterioration of samples will result.

These standards are formulated with principal reference to rock and soil core and samples (A-, B-, N-, size up to 12-inch) taken without special sampling sleeves, tubes, or containers. When samples taken in sleeves or containers, or undisturbed hand-cut samples are specifically intended for laboratory examination or testing to supply design data, such samples should be taken, prepared, cared for, and handled in accordance with Designation E-2 of the Earth Manual. Samples should be shipped to the Division of Research, E&R Center, immediately to avoid deterioration, change in physical properties, and adverse affects on test results. Appropriate logs, sample data sheets, or other pertinent information shall be submitted with the samples.

Location and Stages of Storage

The preparation and retention of an adequate log or description of the core or samples treated in the following paragraphs are basic prerequisites to initiating storage and disposal procedures. Depending on the types of samples and material sampled, such as slaking materials, shales, or sediments that break down upon drying and lose their in-place characteristics during storage, it may be less expensive to drill new holes than to store large quantities of core that would be seldom if ever looked at or would lead to misleading interpretations if inspected years after drilling and storage.

Core and sample storage facilities should be planned with the basic objective of providing storage at as few points within each region as possible, each of which will serve as large a geographic area, project, or group of projects as practicable. The following items outline the requirements and criteria to be used as guides in planning and selecting the storage points:

1. General core storage requirements. -

   a. Provide minimum storage conditions (see Conditions of Storage).

   b. Eliminate unsupervised storage. The storage point should be at the site of a project, investigation, other Bureau office, or in the same town (see Conditions of Storage).

   c. Reduce to a minimum the need for transfer of core and samples from one storage location to another as work on a structure site or project progresses through successive stages of investigation and construction.

   d. Provide accessibility so that minimum travel is required by Bureau personnel and other authorized individuals, such as prospective bidders on construction specifications, and permit easy examination of the core.

e. Before constructing or acquiring new space, canvass existing (Government-owned) unused space, or space initially provided for other purposes but adaptable to core storage. (Examples: Lower floors and galleries of many power and some pumping plants; retention of a building erected for temporary use during construction.)

2. Storage during investigation stages. -

a. Core and samples should be kept at the nearest existing storage facility. A new storage facility should be established only if required by factors such as geography, amount of core anticipated, duration of investigation or convenience of access by engineers and geologists of a new field investigation office. In some instances during periods when actual drilling and sampling operations are in progress, temporary storage at the site may be required to facilitate logging, selection of samples, or ready reference while geologic, soils, or other field studies are in progress. Such temporary onsite storage must be limited to short periods of actual need and must not result in damage or deterioration of the core and samples.

b. When a field office maintaining core storage facilities is closed following preliminary investigations: Dispose of core no longer needed (see Retention of Samples); transfer remaining core to a location where it can be stored most economically. When more extensive exploration is resumed, the core should be reexamined and in some cases must be relogged to relate it to more advanced techniques of geologic appraisal.

3. Storage during construction stage. -

a. As the specifications issuance and construction stage approaches, core and samples secured during investigation stages should remain at their current storage points unless the Regional Director or Construction Engineer requests their transfer to the construction office to facilitate inspection by prospective bidders or for reference and study by their staffs during construction operations.

BEST DOCUMENT AVAILABLE

b. As the close of the construction stage approaches, the Construction Engineer should arrange for the Project or Regional Geologist to select, if required, special samples for future laboratory research testing (see Retention of Samples). Note: Sample selection at this time is more satisfactory than later when personnel most familiar with the core and foundation conditions are no longer available.

c. At the close of construction stage, transfer of responsibility for continued operation of the structure or project from the Construction Engineer to the appropriate O&M official must include specific arrangements for continued storage of core and samples until applicable core retention criteria have been met. The core and samples should remain at the current storage point unless circumstances warrant transfer (such as elimination of or higher priority use of that space).

4. Storage during operation and maintenance stage. -

a. The O&M official directly responsible for the structure, group of structures, or project will maintain all core and samples in storage until length of storage requirements to have been met. He will then immediately initiate the procedures outlined under Disposal of Core and Samples.

b. In the event that responsibility for the structure is to pass from the Bureau to another public or private agency such as a water users' association before the applicable standard core retention periods have expired, the O&M official will request the Regional Director to review the retention criteria.

Conditions of Storage

The minimum conditions for all core and sample storage at all stages are:

1. Weatherproof (dry) storage. - Positive protection against wetting and drying but not against temperature changes. (Cores secured for laboratory test purposes that might be damaged through loss of moisture or freezing should be given appropriate protection.)

2. Protection against access and damage by unauthorized individuals and rodent infestation.

3. Core boxes and samples should be systematically grouped by hole number, investigation site, and project, and stacked to permit reasonably easy access and examination of the core from individual holes without excessive unstacking and moving of adjacent core boxes. Height of core stacks should be consistent with safety regulations and reasonable ease of handling. Core box racks should be provided only when repeated reexamination and study are anticipated and when the time saved by having the boxes separated in units of four or five boxes would be commensurate with the cost of the racks.

4. Adequate records to include final logs, photographs, and inventory of the core and samples stored at each core storage location must be maintained by the office responsible for that storage facility. The records must include name of the feature or investigation site, drill hole number, and number of boxes. The Regional Director's office must maintain a list of the structure or investigation sites for which core is stored at each of the core storage locations within that region.

Length of Storage

1. Proposed structures or projects. - All core and samples secured during site investigations must be retained until the proposed structure(s), unit, or project is built or abandoned by reason of alternate construction or for other reasons with no reasonable chance that the proposed structure(s) will be revived for future consideration. The following are exceptions:

a. Appraisal. - At the termination of reconnaissance stage investigations, such as abandonment of proposed structure site(s) or completion of reconnaissance designs and estimates, the Regional Director should dispose of foundation core and samples and all disturbed soil samples secured in borrow pit investigations for dams, canals, etc. He may delay the disposal in special cases for a definite period of time. Approval of the ACER for disposal or extended retention of appraisal stage core and soil samples is not required.

b. Feasibility. - Disturbed soil samples from borrow pit investigations secured during feasibility stage investigations and not used for testi should be discarded at the termination of the investigation stage as manifested by the approval of the project planning report, unless it is evident that interest in the project is sufficient to assure its continuing development. If, at the end of 1 year, further development work has not materialized, the collected samples should be discarded on the presumption that deterioration has been sufficient to make further tests on such samples unreliable.

Undisturbed soil samples retained on the project can, in all cases, be discarded 1 year after collection, if not tested by then.

2. Specifications design investigations and completed structures or projects. -

a. Borrow pit investigations for design. - Borrow pit soil samples collected for investigations leading to construction should be retained until construction is completed, as evidenced by a contract release except as they are consumed in routine testing. The Principal Designer should be notified of any pending disposal so that any needed samples can be retained.

b. Borrow pit investigations for construction control. - Borrow pit soil samples collected for construction control investigations and field laboratory testing should be discarded after completion of the field laboratory testing except when future use is anticipated.

c. Record samples from fill. - Samples collected for record tests, not consumed in record testing, should be transmitted to the E&R Center for retention unless it appears that the magnitude of the collection is greater than necessary for effective representation of the materials used for construction. Such occasions are rare and should be handled as special problems through communication with the Division of Research, Denver, and the Principal Designer.

d. Foundation core and samples. - All foundation core and samples secured during construction and prior investigation and not consumed in testing may be disposed of when all of the following requirements have been met:

(1) A minimum period of trouble-free operation has passed. The following criteria should be followed in determining the length of a trouble-free operation period:

(a) One year. - Canals and distribution systems including pipelines, minor or small engineering structures, low dikes or embankments, provided no claims are pending.

(b) Five years. - Large or major engineering structures such as dams, power or pumping plants, main feeder canals, main power conduits. For large dams, the 5-year time period should begin after complete reservoir filling. Retain the core from a few representative drill holes for the life of the engineering structure.

(2) Completion of all contractual negotiations and settlement of claims which might involve reinspection or testing of the core or samples.

(3) Expiration of all special agreements or guarantees made by the Bureau with other agencies for the maintenance or performance of Bureau structures which might involve reinspection of core from foundations.

Disposal of Core and Samples

1. General. - The retention of an adequate log or description and photograph(s) of the core and samples are basic prerequisites to initiating the disposal procedures outlined below.

2. Procedures. - When the minimum retention periods and other requirements outlined above have been met, the Regional Director will inform the ACER and request authority to dispose of the core and samples or, if necessary, will recommend continued retention. (This requirement is not applicable to appraisal stage core and samples, see Length of Storage.)

The ACER will review the known and foreseeable requirements and take appropriate action. Such action normally will authorize the Regional Director to:

a. Dispose of all the core and samples.

b. Dispose of all the core and samples except for selected core samples as discussed under Retention of Rock Core Samples.

c. Retain the core in storage for a longer period if warranted by foundation behavior or related incomplete technical studies of the foundation and the engineering structure.

After disposal of the core is authorized and any necessary rock core samples have been secured for Bureau use, the Regional Director shall:

a. Comply with the requirements of any existing State or municipal laws or regulations affecting the region for disposition of the core, representative samples, or hole location data. The Regional Director will make the necessary arrangements to assure he is made aware of any such State, municipal, or local laws when enacted.

b. Consider the desirability of affording the State Geologist's Office, technical schools, colleges, museums, or similar groups in the general area that may be interested in geologic conditions, the opportunity to select samples of the cores before disposal.

c. If Government right-of-way near a constructed facility is available, a recommended disposal procedure suggested would be to place permanent markers in the core boxes, wrap the boxes in plastic, and bury the boxes in a marked location.

Retention of Rock Core Samples

The authorization of the ACER for disposal of rock core and samples for specific structure, group of structures, or project will sometimes include a request that the rock core from a few selected drill holes be retained. Geologic assistance to select the rock core retained should be provided by the Regional or Project Office as appropriate.

1. Rock core samples for laboratory testing. - One phase of the Bureau's foundation research includes the compilation of physical properties, stress-strain, and petrographic data on a range of rock types for correlation and use in preliminary design and estimating studies. Samples for that purpose are tested as time permits and are to be secured only when specifically requested by the ACER. When requested, such sample sets will normally consist of about 20 linear feet of Nx core from each of the major rock types at the site. The length of the individual pieces of rock core should be at least twice the core diameter and selected to avoid pieces with incipient fractures. Each piece must be identified by drill hole number and depth and packed to prevent breakage in shipment.

Boxing and Labeling Drill Core for Storage

1. Procedures. - To facilitate storage, handling, and easy identification of contents, standard core box sizes and labeling procedures should be adopted. The procedures outlined in the following paragraphs are in current use, with minor variations, at many Bureau offices and should be adopted by all offices.

2. Boxing. - Core boxes should be constructed at the lowest cost consistent with providing a sturdy box capable of withstanding a reasonable amount of careful handling, stacking, and shipment when filled with rock core.

3. Labeling. - Each box should be labeled as follows:

_____ Damsite*, D. H. No. _____

Box _____ of _____ boxes

From _____ feet to _____ feet

To facilitate identification when stacked, this information should be shown on one end and the top of each core box. Temporary labeling utilized while drilling a hole must be replaced with permanent labeling which will remain legible after handling, stacking, or storing for long periods.

4. Layout. - Provide a drawing which shows the location of drill holes by stacks in a large or congested storage area so that individual boxes can be retrieved with minimal effort.

---

* Use appropriate term (dam, tunnel, canal, etc.) to identify the type of structure.

BEST DOCUMENT AVAILABLE

APPENDIX A

ABBREVIATIONS USED IN ENGINEERING GEOLOGY
MODIFIED FROM A.A.P.G. COMMITTEE ON STRATIGRAPHIC CORRELATIONS

Words	Abbreviations	Words	Abbreviations
Abundant	abnt	Dead	dd
Acicular	acic	Debris	deb
Agglomerate	aglm	Decomposed	decomp
Aggregate	agg	Decrease, decreasing	decr
Altered, altering, alternating	alt, altng	Dendritic	dend
Amorphous	amor	Dense	dns
Amount	amt	Determine	dtrm
Angular	ang	Detrital, detritus	dtrl
Anhedral	anhed	Diameter	dia
Anhydrite, anhydritic	anhy	Difference	dif
Apparent	ap	Dike	dk
Appears	aprs	Discontinuous	disc
Approximate, approximately	approx	Disjointed	disj
Aragonite	arag	Displaced	disp
Arenaceous	aren	Disseminated	dism
Argillaceous	arg	Dolocast, dolocastic	dolc
Arkose, arkosic	ark	Dolomite, dolomitic	dol
Asphalt, asphaltic	asph	Dozer trench	DT
At	@	Drill hole	DH
Auger hole	AP	Drawing	dwg
Average	avg	Druse, drusy	drsy
Band, banded	bnd	Earthy	rthy
Barite, baritic	bar	Elevation	el
Basalt	bas	Elliptical	elip
Bed	bd	Elongate	elg
Bedded	bdd	Embedded	embd
Bedding	bdg	Enlarged	enl
Bentonite, bentonitic	bent	Equivalent	equiv
Bifurcating	bifur	Estimated	est
Biotite	biot	Euhedral	euhed
Bitumen, bituminous	bit	Evaporitic	evap
Black	blk	Expose, exposed, exposure	exp
Block, blocky	blky	Extrusion, extrusive	extr
Blue, bluish	bl		
Boulder	bldr	Faceted	fac
Botryoidal	btry	Fahrenheit	F
Breccia, brecciated	brec	Faint	fnt
Brittle	brit	Fair	fr
Bright	bri	Fault	flt
Broken	brk	Feldspar, feldspathic	fld
Brown	brn	Ferruginous	Fe
		Fibrous	fib
Calcite, calcareous	calc	Figured	fig
Carbonaceous	carb	Fine, finely	f
Cavernous	cav	Fissile	fis
Casing	cs	Flaggy	flgy
Caving	cvg	Flake	flk (s)
Cement, cemented	cmt	Flaky	flky
Center, centered	cntr	Flat, flattened	flat
Chalcedony	chal	Floating	fltg
Chalk, chalky	chk	Fluorescence	flor
Chert	cht	Foliated	fol
Cherty	chty	Foot, feet	ft
Chloritic, chlorite	chlor	Formation	fm
Clastic	clas	Fossil, fossiliferous	fos
Clay, clayey	cly	Fracture, fractured	frac
Claystone	clyst	Fragment, fragmental	frag
Clean	cln	Fresh	frs
Clear	clr	Friable	fri
Cleave	clv	Frosted	fros
Cleavage	clvg		
Close, closely	clo	Gabbro	gab
Cluster	cls	Generally	gen
Coarse, coarsely	c	Glassy	gl
Cobble	cbl	Glauconite, glauconitic	glau
Columnar	col	Gloss, glossy	glos
Common	com	Gneiss	gns
Compact	cpct	Good	g
Conchoidal	conch	Grade, grades, graded	grd
Concentric	cncn	Grading	grdg
Concretion, concretionary	conc	Grain, grained	gr
Conglomerate	cgl	Granite	grnt
Contact	ctc	Granular	gran
Continuous	cont	Granule	grnl
Contorted	cntrt	Gravel	gvl
Coquina	coq	Gray	gy
Covered	cov	Graywacke	gywke
Crenulated	cren	Greasy	gsy
Crevice	crev	Green	gn
Crinkled	crnk	Gritty	grty
Cross-bedded, cross-bedding	xbd, xbdg	Gypsum, gypsiferous	gyp
Cross-laminated	xlam		
Cross-stratified	xstrat	Hackly	hky
Cryptocyrstalline	crpxl	Hard	hd
Cryptograined	crpgr	Healed	hld
Crystal, crystalline	xl	Heavy	hvy
Cuttings	ctgs	Hematite, hematitic	hem

BEST DOCUMENT AVAILABLE

APPENDIX A

ABBREVIATIONS USED IN ENGINEERING GEOLOGY
MODIFIED FROM A.A.P.G. COMMITTEE ON STRATIGRAPHIC CORRELATIONS - Continued

Words	Abbreviations	Words	Abbreviations
Hexagonal	hex	Object	obj
High	hi	Occasional	occ
Horizontal	hor	Ochre	och
		Odor	od
Igneous	ig	Oil	o
Imbedded	imbd	Oil sand	o. sd
Impression	imp	Oil stain	o. stn
Inch	in	Olive	olv
Included, inclusion	incl	Oolite, oolitic	ool
Increase, increasing	incr	Oomold, oomoldic	oom
Indistinct	indst	Open	op
Indurated	ind	Orange	orng
Intensely	int	Organic	org
Interbedded	intbd	Orthoclase	orth
Intercalated	intcl	Oxidized	ox
Intercrystalline	intxl		
Interfingered	intfr	Part, partly	pt
intergranular	intgran	Parting	ptg
Interlaminated	intlam	Pearl, pearly	prly
Interstitial	intstl	Pebble	pbl
Interval	intv	Pebbly	pbly
Intraformational	intfm	Pellet	pel
Intrusion, intrusive	intr	Permeability	perm
Iron	Fe	Petroleum, petroliferous	pet
Irregular	irr	Phosphate, phosphatic	phos
Irridescent	irid	Pink	pk
		Pisolite, pisolitic	piso
Jointed	jtd	Pitted	pit
Joint opening	jt. op.	Plagioclase	plag
Joint spacing	jt. sp.	Plane	pl
Joints	jts	Plastic	plas
		Plastic Index	PI
Kaolin	kao	Platy	plty
		Polish, polished	pol
Laminated	lam	Poor, poorly	p
Large, larger	lrg	Porcelaneous	porc
Lavender	lav	Porosity, porous	por
Leach, leached	lch, lchd	Possible, possibility	pos
Ledge	ldg	Pounds per square inch	lb/in^2
Lentil, lenticular	len	Pounds per square foot	lb/ft^2
Light, lighter, lightly	lt, ltly	Predominate, predominantly	pred
Lignite, lignitic	lig	Preserved, preservation	pres
Limestone	ls	Primary	prim
Limonite, limonitic	lmn	Prism, prismatic	pris
Limy	lmy	Probable, probably	prob
Liquid limit	LL	Prominent, prominently	prom
Lithic, lithology, lithographic	lith	Pseudo-	psdo
Little	ltl	Purple	purp
Long	lg	Pyrite, pyritized	pyr
Loose	lse	Pyroclastic	pyrclas
Lower	low		
Lumpy	lmpy	Quartz	qtz
Luster	lstr	Quartzite	qtzt
		Quartzitic	qtzc
Magnetic	magn	Quartzose	qtzs
Marlstone	mrlst		
Maroon	mar	Radiate, radiating	rad
Massive	mas	Range, ranging	rng
Material, matter	mat	Rare	rr
Matrix	mtx	Regular	reg
Maximum	max	Remains, remnant	rmn
Median	mdn	Replaced, replacing, replacement	repl
Medium	m	Residue, residual	resd
Member	mbr	Resinous	rsns
Metamorphic	meta	Rhomb, rhombic	rhmb
Mica, micaceous	mica	Rock	rk
Microcrystalline	micxl	Round, rounded	rd
Micrograined	micgr	Rubbly	rbly
Middle	mid		
Mineral, mineralized	mnrl	Sample	spl
Minimum	min	Sand	sd
Minor	mnr	Sandstone	sdst
Minute	mnut	Sandy	sdy
Moderate	mod	Saturated, saturation	sat
Mottled, mottling	mot	Scattered	scat
Mudstone	mdst	Schist, schistose	sch
Muscovite	musc	Secondary	sec
		Sediment, sedimentary	sed
No, non	n.	Selenite	sel
Nodule	nod	Shale	sh
No recovery	NR	Shaly	shy
Number	no.	Siderite, sideritic	sid
Numerous	num	Silica, siliceous	sil

BEST DOCUMENT AVAILABLE

APPENDIX A

ABBREVIATIONS USED IN ENGINEERING GEOLOGY
MODIFIED FROM A.A.P.G. COMMITTEE ON STRATIGRAPHIC CORRELATIONS - Continued

Words	Abbreviations	Words	Abbreviations
Silky	slky	Unconformity	unconf
Siltstone	sltst	Unconsolidated	uncons
Silt	slt	Upper	up
Silty	slty		
Slabby	slab	Variable	var
Slickensided	slks	Varicolored	vcol
Slight, slightly	sl	Variegated	vgt
Small	s	Varved	vrvd
Smooth	sm	Vein	vn
Soft	sft	Vertical	vert
Solution	sol	Very	v
Sorted	srtd	Vesicular	ves
Sorting	srtg	Vitreous	vit
Sphalerite	sphal	Volcanics	volc
Stain, stained, staining	stn	Vug, vuggy, vugular	vug
Standard	Std		
Stippled	stip	Water	wtr
Stone	st	Water level	WL
Strata, stratified, stratification	strat	Wavy	wvy
Streak	str	Waxy	wxy
Striated	stri	Weak	wk
Stringer	strg	Weakly	wkly
Strong	strg.	Weather, weathered	weath
Structure	struc	Welded	wld
Stylolite	styl	Well	w
Subangular	sbang	White	wh
Subhedral	sbhed	Wide, widely	wd
Subrounded	sbrd	With	w/
Sulphur	S		
Surface	surf	Yellow	yel
Tabular	tab	Zone	zn
Test pit	TP		
Texture	tex		
Thick	thk		
Thin	thn		
Throughout	thru		
Tight, tightly	tt		
Trace	tr		
Translucent	trnsl		
Transparent	trnsp		
Tuffaceous	tuf		

Note: Metric unit abbreviations are provided in the Metric Manual.

APPENDIX B
GEOLOGIC DRAWING DRAFTING STANDARDS AND SYMBOLS

This appendix provides guidelines and standards for geologic drawings and overlays. Except as approved for special circumstances, all specifications geologic drawings should be standard size (21 by 36 inches or 10-1/2 by 18 inches). If an oversize product is required, it is preferable to use several standard-size drawings with matchlines. The use of field geologic drawings or field-prepared overlays for specifications drawings is encouraged to eliminate redrafting and to reduce drafting errors. Responsible Geologists and technicians at the E&R Center and Project and Regional Offices should discuss the use of field drawings early in the data collection period to work out details necessary to incorporate field drawings if possible. If field drawings are used, they must use standard geologic symbols.

Explanation Drawings

A single geologic drawing should, if space is available, have its own legend, explanation, and notes. If multiple drawings are used, then a single drawing with general geologic legend, explanation, and notes should be used. Other geologic drawings would only require a note to see the general geologic legend, explanation, and note drawing unless specific notes are required to explain or clarify a particular drawing. Examples are available in most of the recently issued specifications.

Overlays

Overlays for design, topographic, or geology drawings are usually printed in red. Figure B-1, taken from Reclamation Instructions, illustrates the required notations for overlay drawings. All overlay drawings should be inspected for overprinting prior to submittal.

BEST DOCUMENT AVAILABLE

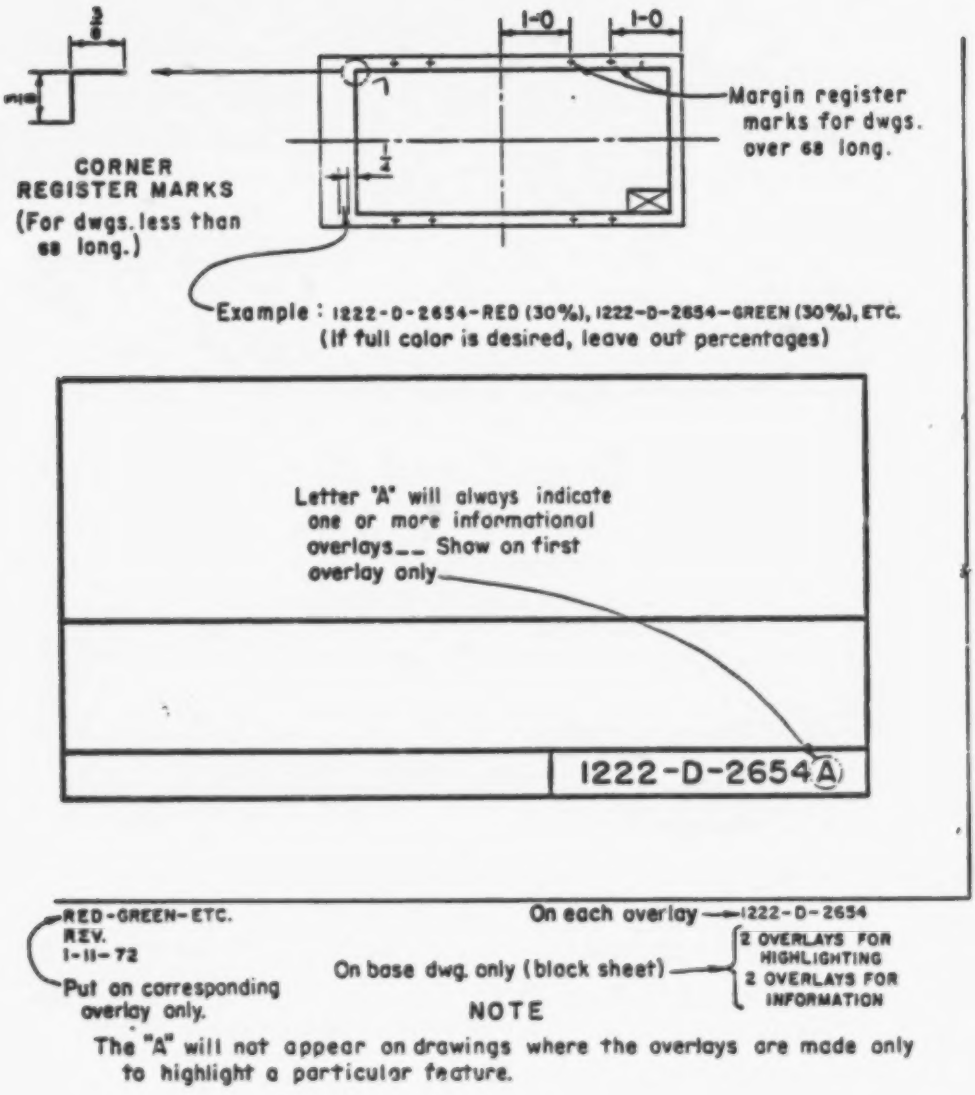

1-0
1-0
Margin register marks for dwgs. over 68 long.
CORNER REGISTER MARKS
(For dwgs. less than 68 long.)
Example : 1222-D-2654-RED (30%), 1222-D-2654-GREEN (30%), ETC.
(If full color is desired, leave out percentages)
Letter "A" will always indicate one or more informational overlays__ Show on first overlay only
1222-D-2654 A
RED-GREEN-ETC.
REV.
1-11-72
Put on corresponding overlay only.
On each overlay → 1222-D-2654
On base dwg. only (black sheet) →
2 OVERLAYS FOR HIGHLIGHTING
2 OVERLAYS FOR INFORMATION
NOTE
The "A" will not appear on drawings where the overlays are made only to highlight a particular feature.

Figure B-1. - Identification of overlays.

Lettering Sizes and Line Weights

Figure B-2 provides guidelines for lettering sizes and line weights to be used for specifications drawings. It is important to remember that specifications drawings are normally half-size, and lettering readable on full-size drawings may not be readable on half-size overlays or drawings. Depending on the scale of the drawing and amount of data shown, good judgment is required in selecting sizes of symbols and the use of abbreviations to avoid "cluttered" drawings.

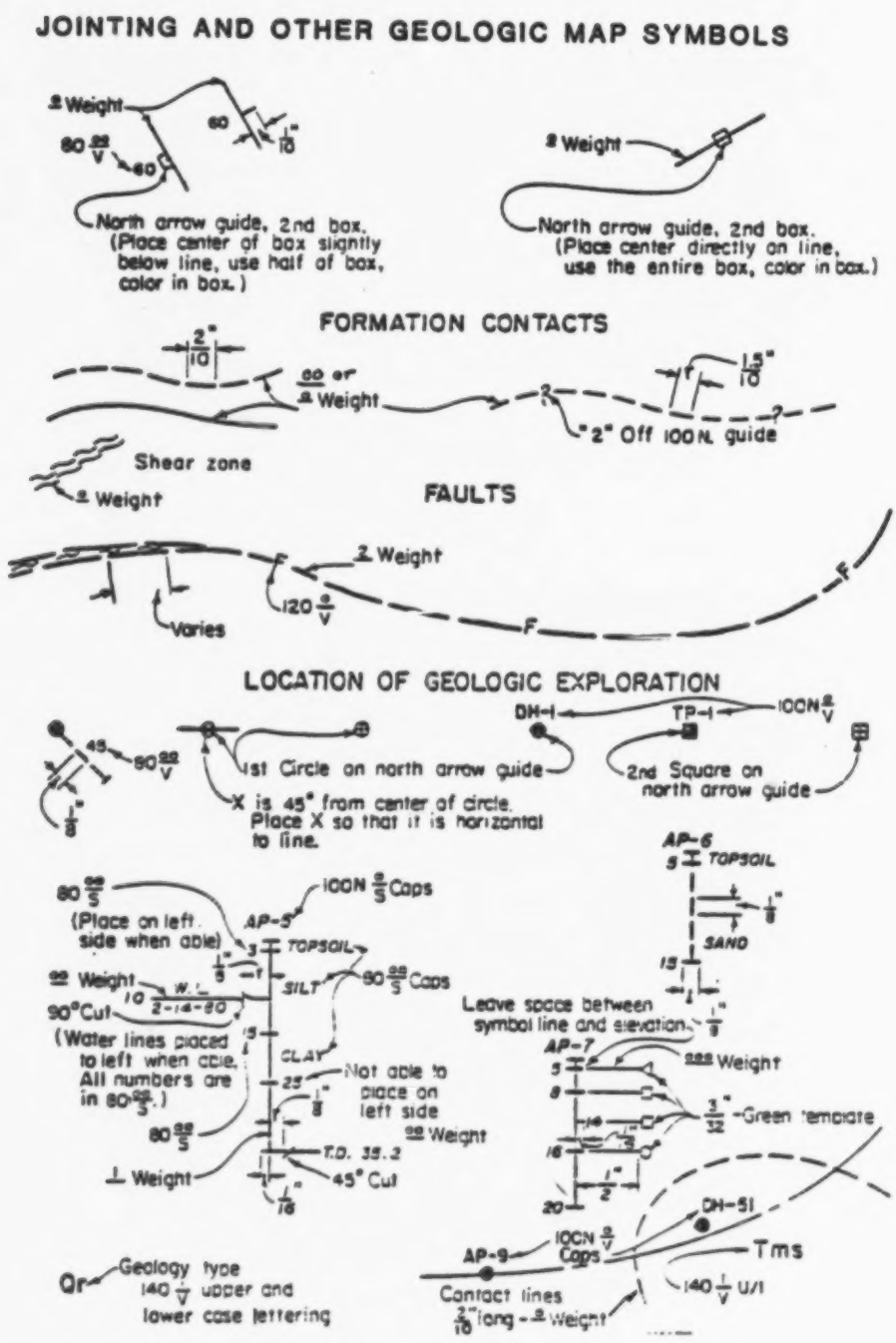

JOINTING AND OTHER GEOLOGIC MAP SYMBOLS
North arrow guide, 2nd box. (Place center of box slightly below line, use half of box, color in box.)
North arrow guide, 2nd box. (Place center directly on line, use the entire box, color in box.)
FORMATION CONTACTS
Shear zone
"2" Off 100 N. guide
FAULTS
Varies
LOCATION OF GEOLOGIC EXPLORATION
1st Circle on north arrow guide
X is 45° from center of circle. Place X so that it is horizontal to line.
2nd Square on north arrow guide
(Place on left side when able)
(Water lines placed to left when able. All numbers are in 80 22/5.)
Not able to place on left side
90°Cut
Leave space between symbol line and elevation
Green template
Geology type
lower case lettering
Contact lines

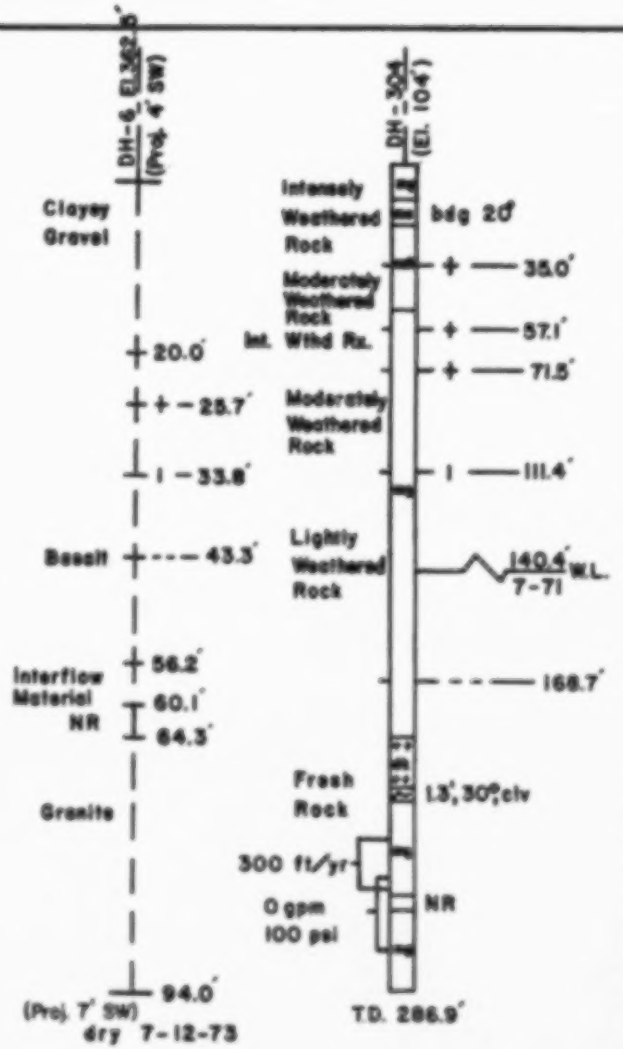
Figure B-2. - Standard lettering sizes and line weights for geologic drawings.

BEST DOCUMENT AVAILABLE

Standard Geologic Map Symbols

Standard map symbols for geologic plans and sections are provided on drawings No. X-D-4247, X-D-4248, and X-D-4249. These drawings include or revise the standard symbols shown in Reclamation Instructions, Part 134. Where optional symbols are shown, judgment should be exercised in the choice of symbols based on the scale of the drawing, complexity of the geology, and amount of detail to be shown.

Symbols depicting attitudes of structural features or properties of materials such as joints, faults, folds, and cleavage should have the strike direction shown if possible. The strike may be shown as either azimuth or the traditional bearing in degrees from north. This procedure will assist those in the field and E&R Center offices who must use the information for analyses. Abstract symbols may be used in lieu of those lithologic symbols shown on drawing No. X-D-4248. If used, lithologic symbols should be shown on the legend, explanation, and notes drawing.



COLLAR DATA: Drill hole number, ground or collar elevation, distance and direction collar of hole is projected normal to section.

CONTACTS OF GEOLOGIC UNITS (standard or abstract symbols may be used).

BEDDING OR CLEAVAGE ATTITUDES.

TOP OF MODERATELY WEATHERED ROCK (depth).

ZONE OF INTENSELY WEATHERED ROCK (depths).

TOP OF LIGHTLY WEATHERED ROCK (depth).

WATER LEVEL and date recorded.

TOP OF FRESH ROCK (depth).

SHEAR ZONE. True thickness, angle of inclination for inclined and horizontal holes or dip for vertical holes, "bdg" or "clv" if parallel to structure, "jt" if parallel to joint set. Shears less than 1/4-inch thick may not be shown.

PERMEABILITY TEST. Packer interval, loss and pressure or "k".

TOTAL DEPTH, also distance and direction bottom of hole is projected normal to section.

ALWAYS THINK SAFETY

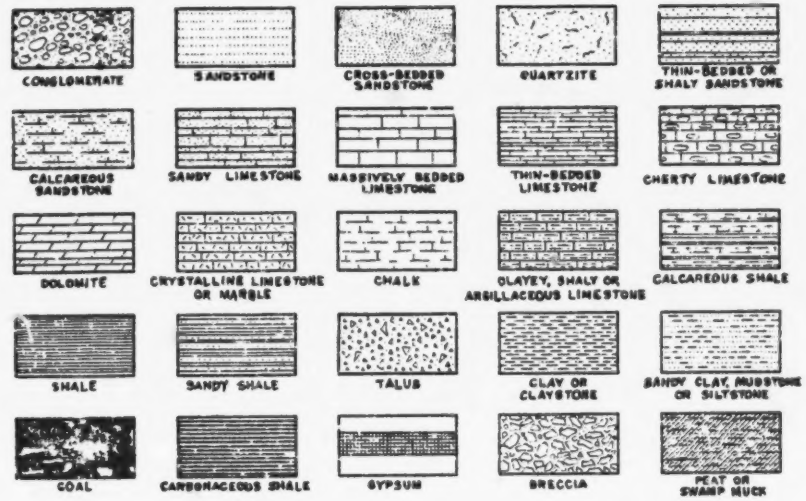
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR ACER SPECIFICATIONS

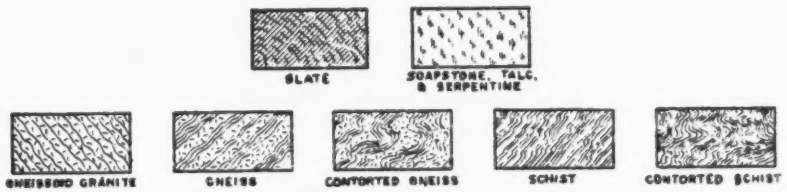
Examples of Drill Hole Symbols for Geologic Cross Sections

DRAWN CAIN	SUBMITTED
TRACED	RECOMMENDED
CHECKED	APPROVED
DENVER CO. OCT. 28, 1981	X-D-4247

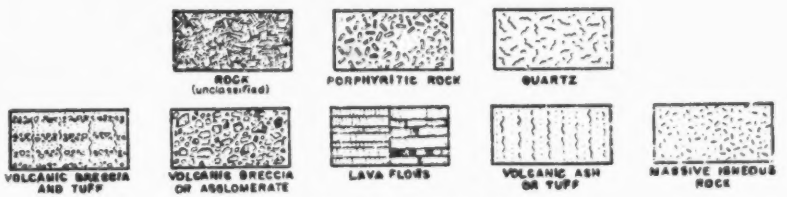
BEST DOCUMENT AVAILABLE



SEDIMENTARY ROCKS



METAMORPHIC ROCKS



IGNEOUS ROCKS

SURFICIAL MATERIAL

MISCELLANEOUS SYMBOLS

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR ACER SPECIFICATIONS

Standard Geologic Symbols used for Geologic Sections and Columnar Sections

DRAWN CAIN	SUBMITTED
TRACED	RECOMMENDED
CHECKED	APPROVED
DENVER, CO. OCT. 28, 1981	X - D - 4248

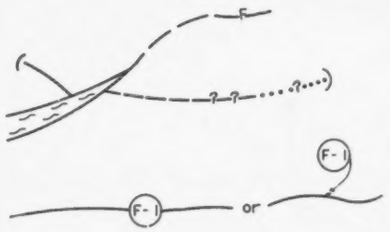
BEST DOCUMENT AVAILABLE

MAP SYMBOLS FOR GEOLOGIC FEATURES

CONTACTS

Solid where definite or located accurately (accuracy depends on survey control and scale of drawing), dashed where approximate, queried where inferred, dotted where concealed. Use appropriate attitude symbol for orientation of contact.

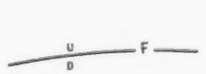
SHEARS AND FAULTS



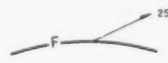
Shear and fault zones shown solid where definite or located accurately (accuracy depends on survey control and scale of drawing), dashed where approximate or projected, queried where inferred, dotted where concealed. (Symbol indicates probable limit of continuity.

Symbol shows true thickness if over [2] feet or [1] meter (depending on scale of drawing). Letter 'F' and number (F-1) may be used for identifying faults on drawings and reference for discussion.

NOTE: Line weights for faults should be heavier than contacts etc. Faults or shears can be lettered with 'F', 'f', 'S' or 's' if needed to distinguish them from contours, contacts or other lines, especially when overlays are not used.



Fault showing relative vertical movement U, up and D, down

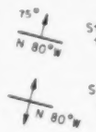


Fault, showing bearing and plunge of relative movement of downthrown (D) block

Thrust or reverse fault, barbs on side of upper plate

Fault, showing bearing and plunge of grooves, striations, or slickensides

Fault, showing relative horizontal movement



Strike and dip of fault or shear

Strike of vertical fault or shear

BEDDING

Strike and dip of beds

Horizontal beds

Strike of vertical beds

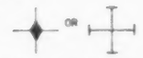
Approximate or estimated strike and dip

Strike and dip of overturned beds

FOLIATION, SCHISTOSITY, OR CLEAVAGE

Strike and dip of foliation, schistosity or cleavage

Strike of vertical foliation schistosity or cleavage



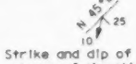
Horizontal foliation, schistosity or cleavage

LINEATION

Bearing and plunge of lineation

Horizontal lineation

Vertical lineation



Strike and dip of beds and plunge of lineation

Strike and dip of foliation or schistosity and plunge of lineation

JOINTS

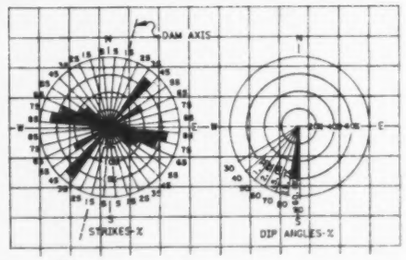
Strike and dip of joint

Horizontal joint

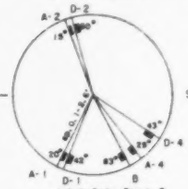
Strike of vertical joint

Strike and dip of multiple joints

(Dip symbols shifted along strike for legibility, observations located at point of intersection)

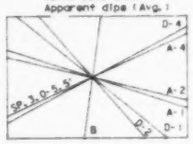


Joint Rose: Histogram presentation of joint strike or dips for a given joint sampling.

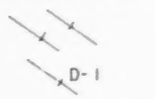


Joint Sets-Block E
Average Attitudes

Joint Set Diagram: Provides average attitudes of joint sets occurring in a specified area, such as a 'foundation block', tunnel observation, abutment, or entire map. Spacing and or percent of distribution from contour plotting may also be shown.

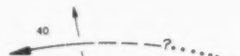


Apparent Dip Block: Illustrates average orientation of joint sets in plane of geologic section for a specific area, or along entire section. Spacing or percent distribution may be shown.



Apparent dip or joint traces on sections, test pit, trench, and tunnel logs.

FOLDS



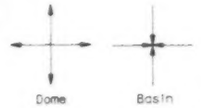
Anticline, showing trace of axial plane and bearing and plunge of axis. Dashed where projected or approximate, queried where inferred, dotted where concealed.

Syncline, showing trace of axial plane and bearing and plunge of axis. Dashed where projected or approximate, queried where inferred, dotted where concealed.

Overturned anticline, showing trace of axial plane, direction of dip of limbs and bearing and plunge of axis.

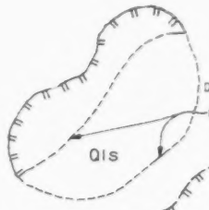
Monocline, showing trace and plunge of axis.

Overturned syncline, showing trace of axial plane and direction of dip of limbs and bearing and plunge of axis



MISCELLANEOUS SYMBOLS

LANDSLIDES



Definite scarp

Limits of slide mass

Scarp location approximate, queried where inferred

Strike and dip of failure plane

DIKES AND SILLS

Strike and dip dike or sill

Horizontal sill

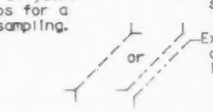
Strike of vertical dike or sill

OTHER SYMBOLS FOR PLANAR FEATURES

These symbols may be used for attitudes of veins or other structural features. They must be explained on explanation and note drawing

GEOLOGIC EXP

5' x 7' 37 Exploration or size.).



Exploration tu on surface ma if on elevati

Exploration ad if projected, or section).

Mine adit (app

Open pit, quar

Sand, gravel p

GEOPHYSI

10 Resistivity so

Resistivity so

R-9 Seismic shot p

Seismic shot p

Seismic shot p and geophone

GR-26 Other geophys and suffix GP

EXAMPLES OF SYM

R4B2 Radial Jacking Te

U4B2 Uniaxial Jacking

PJ Plate Jack Test

DRILL HOLE AN

SURFACE GEOLOGY O

VERTICAL DRILL assumed vert deflection.

HORIZONTAL AND length, and d down, plus up trace of hole

AP-201 Auger hole (Pr

TP-301 Test pit (back

ELEVAT

DH-292 90° VERTICAL SURFA indicates tha of plan isopa maps, open ci

INCLINED SURFA length, and d indicates dow indicates col indicates whe of plan, isop short dashes

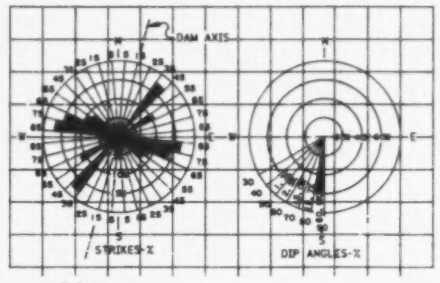
BEST DOCUMENT AVAILABLE 136

BEST DOCUM

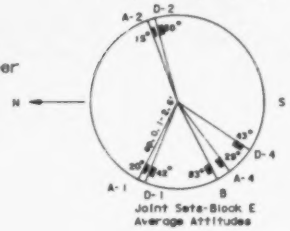
YMBOLS FOR GEOLOGIC FEATURES

tely (accuracy
f drawing);
re inferred;
te

e definite or located
y control and
ximate or projected;
concealed. (Symbol
.
r [2] feet or
wing). Letter 'F' and number
ults on drawings



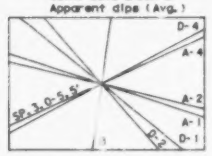
Joint Roses Histogram presentation of joint strike or dips for a given joint sampling.



Joint Sets-Block E
Average Attitudes

Joint Set Diagrams Provides average attitudes of joint sets occurring in a specified area, such as a 'foundation block', tunnel observation, abutment, or entire map. Spacing and or percent of distribution from contour plotting may also be shown.

Joint Sets-Block E
Apparent dips (Avg.)



Apparent Dip Blocks Illustrates average orientation of joint sets in plane of geologic section for a specific area, or along entire section. Spacing or percent distribution may be shown.

Apparent dip or joint traces on sections, test pit, trench, and tunnel logs.

fault, barbs
plate

and dip of
r shear

of vertical
r shear

joints
strike for
located at

FOLDS

Anticline, showing trace of axial plane and bearing and plunge of axis. Dashed where projected or approximate; queried where inferred; dotted where concealed.

Syncline, showing trace of axial plane and bearing and plunge of axis. Dashed where projected or approximate; queried where inferred; dotted where concealed.

Overturned anticline, showing trace of axial plane, direction of dip of limbs and bearing and plunge of axis.

Monocline, showing trace and plunge of axis.

Overturned syncline, showing trace of axial plane and direction of dip of limbs and bearing and plunge of axis

Dome Basin

MISCELLANEOUS SYMBOLS

LANDSLIDES

Definite scarp
Limits of slide mass
Scarp location approximate, queried where inferred

Strike and dip of failure plane

DIKES AND SILLS

Strike and dip dike or sill

Horizontal sill

Strike of vertical dike or sill

OTHER SYMBOLS FOR PLANAR FEATURES

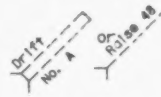
These symbols may be used for attitudes of veins or other structural features. They must be explained on explanation and note drawing

SYMBOLS FOR LOCATION OF EXPLORATION AND TESTING

GEOLOGIC EXPLORATION OR MINING

5'x 7' ◩ 37 Exploration or mine shaft (approximate depth and size.).

Exploration tunnel (dashed if projected on surface map or projected to sections, solid if on elevation plan map or along section.)



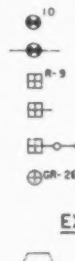
Exploration adit, drift, raise or winze (dashed if projected, solid if on elevation plan map or section).

Mine adit (approximate length and size).

Open pit, quarry or mineral prospect pit.

Sand, gravel pit.

GEOPHYSICAL DATA POINTS



Resistivity sounding
Resistivity sounding with spread direction
Seismic shot point
Seismic shot point with spread direction
Seismic shot point with spread direction and geophone locations.
Other geophysical data points -- use the symbol and suffix GR for gravity, MG for magnetometer.

EXAMPLES OF SYMBOLS FOR SPECIAL TESTS

R4B2 Radial Jacking Test
U4B2 Uniaxial Jacking Test
GJ Plate Jack Test

SR Stress Relief Test
IS In Situ Shear Test

DRILL HOLE AND TEST PIT SYMBOLS

SURFACE GEOLOGY OR LOCATION OF EXPLORATION

VERTICAL DRILL HOLE. Dip may be useful if hole is assumed vertical but survey data indicates deflection.

HORIZONTAL AND INCLINED DRILL HOLE. Bearing, projected length, and average angle from horizontal (minus indicates down, plus up) are shown. Single or double line for trace of hole depends on scale of drawing.

● AP-201 Auger hole (Prefixes: AP=Power Auger, AH=Hand Auger)

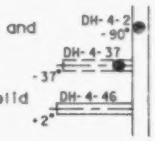
■ TP-301 Test pit (backhoe, bulldozer, hand dug)

ELEVATION PLAN MAPS

DH-292 ○ 90°

VERTICAL SURFACE DRILL HOLE. Solid black circle indicates that hole penetrates elevation of plan isopach, structural or bedrock contour maps; open circle indicates that it does not.

INCLINED SURFACE DRILL HOLE. Bearing projected length, and average angle from horizontal (minus indicates down, plus up) are shown. Open circle indicates collar of hole; solid black circle indicates where hole intersects elevation of plan, isopach of contour maps; short dashes above, long dashes below.



VERTICAL UNDERGROUND DRILL HOLE. Collared at invert or tunnel or drift. Also solid black where penetrates a lower elevation.

INCLINED UNDERGROUND DRILL HOLE. Similar to inclined drill holes on surface maps.

HORIZONTAL UNDERGROUND DRILL HOLE. Usually collared near tunnel springline elevation. Includes same data as cross section drill holes.

STRUCTURAL CONTOUR EXCAVATION GEOLOGY MAPS

Drill hole symbols used for vertical horizontal or inclined surface and underground holes are similar to ELEVATION PLAN MAPS except black circle indicates where hole penetrates excavation surface or structure. Short dashes above, long dashes below. Undergound holes that do not penetrate excavation or structure generally are not shown.

SPECIAL PURPOSE SYMBOLS AND SUFFIXES FOR EXPLORATION HOLES

When the geologist wishes to emphasize or call 'visual' attention on a map to special type of drilling or sampling, measurements (repeated water level readings), logging methods (gamma, resistivity logs) for completed work, he/she should;

(a) Use the standard solid circle symbol ● supplemented with other markings of his choice, which will provide the desired visual emphasis on that particular map such as ● ◉ ■, or

(b) Use the standard solid circle with an appropriate prefix or suffix to the drill hole number such as; PR-106 for penetration resistance.

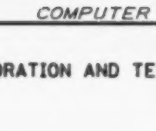
SUFFIX AND PREFIX SYMBOLS

DH	Drill hole	CH	Churn Drill
PR	Penetration Resistance	OW	Observation Well
VT	Vane Test Hole	Examples	
CP	Clam Shell	DH-103 (PR)	
DC	Dutch Cone	DH-DN-103	
PT	Pitcher	PR-103	
DN	Denison	DH-107 (DN/PR)	

(C) Combine methods 'a' and 'b'

In every case the special symbol (and suffix) must be shown and adequately defined in the General Geologic Explanation, Legend and Notes Drawing

TRENCH SYMBOLS



Exploration trenchs show with single line if small-scaled drawing, or congested, or show width with or without major geological facts. Prefix DT indicates dozer trench, BHT indicates backhoe trench. Letters indicate stationing.

SYMBOLS FOR WORKING OR PROGRESS DRAWINGS

◑ DH-103 Drilling in progress

○ DH-104 Proposed drill hole

○ AP-203 Proposed auger hole

□ TP-205 Proposed test pit

DT-301 Proposed trench

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR ACER SPECIFICATIONS
STANDARD GEOLOGIC MAP SYMBOLS FOR GEOLOGIC DRAWINGS

GEOLOGY E & R CENTER STAFF TECHNICAL APPROVAL
DRAWN M.D. BUSTILLOS SUBMITTED
CHECKED APPROVED

DENVER, COLORADO COMPUTER DRAFTING SEPTEMBER 24, 1981

X-D-4246

ENGINEERING SUPPORT BRANCH
COMPUTER DRAFTING SECTION

BLE

BEST DOCUMENT AVAILABLE

136A

APPENDIX C

GEOPHYSICAL SERVICES AND GEOPHYSICAL EQUIPMENT CAPABILITIES

This appendix provides information on the available services and equipment and equipment capabilities and requirements for geophysical investigations conducted by or coordinated by the Geologic Services Branch, Geophysics Section.

Borehole Geophysical Logging

The Geophysics Section has a geophysical borehole logging truck equipped to provide in situ measurements on various foundation properties and borehole parameters. The geophysical logs can be used to validate and supplement drill hole logs or can be used exclusively when coring is considered unnecessary, impractical, or too expensive.

The logging system is mounted on an International, Series 2200, twin-axle diesel chassis. The truck is equipped with a portable gas-powered generator and can function as an independent unit.

The logging unit is equipped with a seven-conductor, double strand 5/16-inch steel cable and has a total depth capability of 3,000 feet. The cable and downhole probes are rated at 250 °F and up to 10,000 lb/in^2. While no minimum borehole depth is established, generally boreholes less than 30 feet deep are impractical to log due to the length of the downhole probes, some of which are as long as 20 feet.

Time required for logging will vary depending on borehole depth and condition and the number and type of logs required. In moderately deep holes (150 to 500 feet), each logging pass including setup time requires approximately 1 hour. Present cost for the borehole logging truck and operator is approximately $300 per 8-hour day, including travel time and per diem.

Generally, the best logs are obtained from uncased, fluid-filled boreholes. However, several types of logs, when run inside steel or PVC casing, usually will produce good results. Since borehole parameters such as variations in borehole diameter, the presence of various drill muds or fluids, and casing or grout will severely affect many of the logs, a detailed description of the borehole completion is necessary for correct interpretation of the logs. Table C-1 provides a listing of the log types which are presently available and an indication of any restrictions or borehole completion requirements.

If you have any questions regarding specific applications or scheduling, please contact personnel in the Geophysics Section in the Geologic Services Branch, telephone FTS 234-5732.

Equipment Used or Furnished by the Geophysics Section

Seismic Equipment

Seismographs. - The following seismographs are maintained by the Geophysics Section:

24-channel portable refraction seismograph system, SIE RS-44 with SIE R6 drywrite recorder. Self-contained power source and built-in blaster.

12-channel portable signal enhancement seismograph system, geoMetrics/ nimbus ES-1210F with CRT display and built-in drywrite recorder. Powerpack, blaster, and digital tape recorder.

6-channel portable signal enhancement seismograph system, Bison 1580, with CRT display and SIE R6 drywrite recorder. Self-contained power source and blaster.

Uses: Seismic refraction, reflection, uphole, downhole, and crosshole methods.

4-channel portable engineering seismograph system, Sprengnether VS-1200, with built-in drywrite recorder and self-contained power source. Orthogonal seismometer with 2,100 feet of cable.

Uses: Blast vibration monitoring, ambient seismic noise monitoring, and site selection and evaluation.

Geophone cables for surface surveys. - Portable geophone cables with 12 takeouts and 50-foot leader wire on each end. Available with the following takeout spacing:

One 5-foot	Four 1-meter
Two 20-foot	Four 5-meter
Two 50-foot	Two 15-meter
Two 100-foot	Four 30-meter

Thirteen 3-foot cables with three takeouts for grouping geophones. Use with above cables.

Two 100-foot extension cables.

One 600-foot extension cable.

Sensors for surface surveys. - Seventy-five vertical geophones, Mark Products L-1. Fourteen horizontal geophones, Mark Products L-1H.

Sensors for downhole surveys. - One velocity cable with 12 hydrophones at 10-foot spacing. Requires 3-inch-minimum-diameter, fluid-filled hole; 500-foot maximum depth.

One shallow well seismometer, three detectors, orthagonal, Mark Products L-1-3DS. Requires 5-inch-minimum-diameter hole; 50-foot maximum depth.

Two sidewall-clamped geophones, three detectors, orthagonal, Mark Products L-10-3D. Requires 3-inch-minimum-diameter hole; 500-foot maximum depth.

BEST DOCUMENT AVAILABLE

Sources for surface surveys. - Three sledge hammers with solid-state triggers.

Three EBW (Exploding Bridgewire) blasting sets - one modified for radio shooting.

One Betsy shotgun source, weight 250 pounds.

Sources for downhole surveys. - One sparker, Simplex 1000 joule. Requires 2-inch-minimum-diameter, fluid-filled hole; 500-foot maximum depth.

One Bison downhole hammer. Requires 4-inch-minimum-diameter hole; 500-foot maximum depth.

Resistivity Systems

Shallow survey equipment (0 to 100 feet)*. - One Soiltest R50/60, output 750 volts, separate transmitter and receiver, rechargeable transmitter (16 pounds).

One Bison 2350A, output 540 volts, transmitter and receiver in same case (14 pounds).

One Bison 2350B, output 720 volts, transmitter and receiver in same case (14 pounds).

Medium depth survey equipment (0 to 300 feet)*. - One Bison 2390, output 1000 volts, separate transmitter and receiver, both rechargeable (16 pounds each).

Deep survey equipment (0 to 1,000 feet or more)*. - One Geotronics, output 5000 volts, FT-10 transmitter (85 pounds), R-401, receiver (10 pounds), B-2 generator (160 pounds), rechargeable receiver.

---

* Depth using Wenner arrays and depends on soil and/or rock resistivities.

Uses: Soundings determine variation of resistivity with depth and thickness of layers:

Corrosion and grounding mat surveys
Depth to sand, gravel, bedrock, or water-saturated layers
Geothermal exploration (deep soundings)

Profiling determines lateral variations in resistivity:

Sand and gravel deposits
Faults and fault zones
Abrupt horizontal changes in types of earth materials.

Borehole Logging Equipment

Portalogger. - Widco model PLA-PRG, records natural gamma, self-potential, and single point resistance. Requires 1-1/2-inch-minimum-diameter hole, fluid-filled for self-potential and resistance. Portable battery powered. Maximum depth 1,000 feet.

Logging trucks. - Comprobe truck-mounted logger on 1976 1-ton Chevrolet Suburban. Records natural gamma, self-potential, single point resistance, and caliper. Requires 2-inch-minimum-diameter hole, fluid-filled for self-potential and resistance. Maximum depth 3,000 feet.

Comprobe truck-mounted logger on 1977 International. Complete logging functions. See "Geophysical Borehole Logging Capabilities" for details.

Miscellaneous Equipment

Borehole television camera. - Sperry model 3000, truck-mounted. Requires 3-inch-minimum-diameter hole, dry or clear water filled; 2,000-foot maximum depth (1,600-foot in water).

Uses: Geologic boreholes. - Surveys for core orientation, determination of dip and strike of planar structures intercepting a borehole, examination of areas of high core loss.

Water wells and inclinometers. - Surveys for determination of casing and screen condition, iron bacteria, or other problems.

Horizontal pipes or drains. - Surveys for joint continuity, breaks, or alinement. Deflection measurements in 10-inch and larger drain tubing.

Temperature logger. - Bureau-designed, portable, self-contained, accuracy to one-hundredth degree. Requires 3/4-inch-diameter hole. Two with 500-foot- and one with 1,000-foot-deep capabilities.

Uses: Termperature surveys for gradients, aquifers, ice lenses, geothermal.

Borescope. - National Statham, Inc. Requires 1-1/4-inch-minimum-diameter hole, dry or clear water filled. Maximum depth 46.5 feet.

Fluorometer. - Turner model 111, with automatic servo balancing for fluorescence measurements. Requires 110 volts.

Magnetometer. - McPhar Model M700, battery-powered, vertical field magnetometer.

Uses: Deep basement studies. Definition of magnetic subsurface features (near surface). Delineate igneous intrusive features.

Table C-1

Borehole Geophysical Logs
Available from the Engineering and Research Center
April 1981

Name of Log - - - - - - Name of Tool	Physical Property Measured (units of measurement)	Applications	Hole Completion and Restrictions	Recording Method	Special Features and Comments
Self Potential - - - - - - - S.P. Probe	Natural Electrical Potential Developed in the Formation (millivolts)	Differentiates High Vs. Low Porosity; Useful for Stratigraphic Correlation	Minimum Hole Diameter - 2 Inch; Borehole Must Be Uncased and Fluid-Filled (Mud or Water)	Analog Stripchart and/or Digital Magnetic Tape	Not Affected By Variations in Borehole Diameter Due to Washouts or Bit Size Changes. Not Affected By Deep Mud Invasion. Best Logs Obtained in Low to Moderate Formation Resistivities. Can be Run Simultaneously With Other Logs
Single Point Resistance - - - - - - - - - - - - Single Point Probe	Effective Resistance of the Formation (ohms)	Determine Variation in Formation Resistance; Useful for Stratigraphic Correlation; Ideal for Locating Coal Beds or Low Resistance Strata	Minimum Hole Diameter - 2 Inch; Borehole Must Be Uncased and Fluid-Filled (Mud or Water)	Analog Stripchart and/or Digital Magnetic Tape	Severely Affected By Variations in Borehole Diameter Due to Washouts or Bit Size Changes; Severely Affected By Variation in Drill Mud Resistivity; Not Possible to Determine True Formation Resistivity for Quantitative Interpretation; Can Be Run With Other Logs
16-64 Inch Normal Resistivity - - - - - - - - - 16-64 Normal Probe	Apparent Resistivity of the Formation (ohmmeters^2/meter)	Estimation of Formation Resistivity; Formation Water Quality; Estimation of Porosity; Useful for Stratigraphic Correlation	Minimum Hole Diameter - 3 Inch; Borehole Must Be Uncased and Fluid-Filled (Mud or Water)	Analog Stripchart (Dual Trace) and/or Digital Magnetic Tape	Affected By Variations in Borehole Diameter Due to Washouts or Bit Size Changes; Log Response is Best With Low to Medium Formation Resistivities and When the Formation Resistivity is Less than the Borehole Fluid Resistivity

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

Name of Log - - - - - - Name of Tool	Physical Property Measured (units of measurement)	Applications	Hole Completion and Restrictions	Recording Method	Special Features and Comments
Guard or Focused Log - - - - - - - - - - - Guard Probe	Apparent Resistivity of the Formation (ohmmeters^2/meter)	Estimation of Formation Resistivity, and Formation Water Quality; Estimation of Porosity; Useful for Stratigraphic Correlation	Minimum Hole Diameter - 3 Inch; Borehole Must Be Uncased and Fluid-Filled (Mud or Water)	Analog Stripchart and/or Digital Magnetic Tape	Affected By Variations in Borehole Diameter Due to Washouts or Bit Size Changes; Log Response is Best With High Resistivity Formations and When Formation Resistivity is Greater Than the Borehole Fluid Resistivity
Natural Gamma Ray - - - - - - - - - - Gamma Probe	Natural Gamma Radiation Emitted From Unstable Uranium, Potassium and Thorium (counts/second)	Determine Variations in Lithology; Provide Indications of Shaliness or Clay Content; Useful for Stratigraphic Correlation	Minimum Hole Diameter - 2 Inch; Can Be Run Through Steel Casing, Drill Pipe, or PVC Casing; Borehole May Be Dry or Fluid-Filled	Analog Stripchart and/or Digital Magnetic Tape	Not Significantly Affected By Variations in Borehole Diameter Due to Washouts or Bit Changes; Can Be Run Simultaneously With Other Logs
Dual Detector Density - - - - - - - - - - - - Dual Detector Gamma-Gamma Probe	Electron Density of the Formation (counts/second) Note: Compensation Equations Allow A Calculated Density to Be Obtained in g/cc or lbs/ft^3	Estimation of Bulk Density and Porosity; Determine Variations in Lithology; Useful for Stratigraphic Correlation; Determination of Degree of Weathering and Cavity Development	Minimum Hole Diameter - 3 Inch; Maximum Hole Diameter - 18 Inch; Best Log Response Obtained if Borehole Is Uncased and Fluid-Filled (Mud or Water) Log Can Be Run in Dry Holes and Through Steel or PVC Casing if Washouts Behind Casing are Considered	Analog Stripchart (Dual Trace) and/or Digital Magnetic Tape	Severely Affected By Variations in Borehole Diameter Due to Washouts or Bit Diameter Changes; Log is Also Affected By Changes in Borehole Fluid Density, Mud Cake, Casing Collars, or Centralizers, and Telescoped Casing. The Probe Utilizes a 125 millicurie Radioactive Source; Can Be Run Simultaneously With Other Logs

Name of Log - - - - - - Name of Tool	Physical Property Measured (units of measurement)	Applications	Hole Completion and Restrictions	Recording Method	Special Features and Comments
Neutron-Porosity Log - - - - - - - - - - Neutron Probe	Hydrogen Content of the Formation (counts/second)	Estimation of Saturated Porosity and/or Moisture Content; Useful for Stratigraphic Correlation; Determination of Degree of Weathering and Cavity Development	Minimum Hole Diameter - 2 Inch; Best Log Response Obtained if Borehole is Uncased; Borehole Must Be Fluid-Filled (Mud or Water); Log Can Be Run Through Steel or PVC Casing if Washouts Behind Casing Are Considered	Analog Stripchart and/or Digital Magnetic Tape	Severely Affected By Variations in Borehole Diameter Due to Washouts or Bit Diameter Changes. Generally Used for Qualitative Porosity Determination. Probe Utilizes a 3-curie Radioactive Source; Can Be Run Simultaneously With Other Logs
Velocity Log - - - - - - - - - - 3 Receiver Velocity Probe	Compressional Wave Travel Time Through the Borehole Medium - (microseconds/foot); Amplitude of the Acoustic Pulse (volts)	Measurement of the Compressional Wave Velocity; Estimations of Porosity and Fracturing; Useful for Stratigraphic Correlation; Provide Velocity Control for Seismic Refraction and Reflection Surveys; Estimation on Strength of Materials and Degree of Weathering	Minimum Hole Diameter - 3 Inch; Borehole Must Be Uncased and Fluid-Filled; Velocity of the Medium Should Exceed That of the Borehole Fluid	Analog Stripchart and/or Digital Magnetic Tape	Severely Affected By Variations in Borehole Diameter Due to Washouts; Probe Utilizes Multiple Receivers for Obtaining Travel Times Which Eliminates the Need for Fluid Delay Correction

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

Name of Log - - - - - - Name of Tool	Physical Property Measured (units of measurement)	Applications	Hole Completion and Restrictions	Recording Method	Special Features and Comments
Sonic Variable Density - - - - - - - - - - - Single Receiver 1.5 Foot Sonic Probe	Variations in Travel Time of an Acoustic Pulse Through the Borehole Medium (microseconds/1.5 feet)	Detection of Thin Clay Seams, Open Partings, Fractures and Weathered Rock. Evaluation Quality of Cement Bond or Grouting Outside Casing	Minimum Hole Diameter - 2 Inch; Borehole Must Be Fluid-Filled (Mud or Water) and Uncased Except for Cement Bond Testing. Log Can Be Run Through PVC if Formation Velocity is Greater Than ≈6600 ft/sec	Electrostatic Film	Severely Affected By Variations in Borehole Diameter Due to Washouts; Probe Utilizes Only a Single Receiver Which allows Only Estimation of Compressional Wave Velocity; Signal is Recorded in a Form Which Allows Display of Multiple Arrivals of the Acoustic Pulse
Seisviewer or Televiewer Log - - - - - - - - - - - - Acoustic Televiewer Probe	Measures Amplitude of Acoustic Signal Reflection Off Borehole Wall (Unit of Display is a Light Intensity on an Oscilloscope Similar to an Actual Photograph of the Borehole Wall)	Detection and Orientation of Joints, Clay Seams, Bedding Planes, and Fractures	Minimum Hole Diameter - 3 Inch; Borehole Must Be Uncased and Fluid-Filled (Mud or Water); Maximum Hole Diameter - 18 Inches	Polaroid Film - One Photograph Each Five Feet of Borehole	This Log Provides an Alternative to the Borehole Television Surveys When Conditions Will Not Allow Visual Inspection of the Borehole; Probe Contains a Fluxgate Magnetometer for Orienting Strikes of Planar Features
Acoustic Caliper - - - - - - - - - - Acoustic Televiewer Probe	Measures Travel Time of Acoustic Signal Reflection Off Bore-Hole Wall or Casing	Measures Small Changes in Borehole Diameter Resulting From Drilling, Open Partings, Joints, Clay Seams, Fractures, and Cavities	Minimum Hole Diameter - 3 Inch; Borehole Must Be Fluid-Filled (Mud or Water); Maximum Diameter - 18 Inches	Analog Stripchart and/or Digital Magnetic Tape	

Name of Log - - - - - - Name of Tool	Physical Property Measured (units of measurement)	Applications	Hole Completion and Restrictions	Recording Method	Special Features and Comments
Temperature Log - - - - - - - - - - - Pulsed Temperature Probe	Temperature of the Borehole Fluid (counts/second) Note: Calibration Equations Allow Conversion to Actual Temperatures in Degrees Fahrenheit	Detection of the Source of Moving Water in the Borehole; Determine Geothermal Gradient; Values Often Used For Correction of Resistivity Logs	Minimum Hole Diameter - 2 Inch; Borehole Should Be Fluid-Filled and Allowed to Reach Thermal Equilibrium. Best Logs Are Obtained in Uncased Boreholes But Can Be Run in Casing	Analog Stripchart and/or Digital Magnetic Tape	If the Log is Run in a Cased Borehole, Only Major Sources of Moving Water Will Be Detected
Water Sampler	———————	Obtain Fluid Samples Within the Borehole At Predetermined Depths	Minimum Hole Diameter - 3 Inch	Sample Volume = 1 liter	
Casing Collar Locator - - - - - - - - - - - CCL	Variations in the Probes Magnetic Field When a Ferrous Material is Encountered or Changes in Thickness (i.e., Casing Coupling)	Detection of the Bottom of Steel Casing; Location of Steel Couplings or Centralizers	Minimum Hole Diameter - 2 Inch	Analog Stripchart	Can Be Run Simultaneously With Other Logs
Caliper Log - - - - - - - - Mechanical Caliper Probe	Variations in Borehole Diameter (inches)	Measures Changes in Borehole Diameter. Detect Open Cavities, Washed Zones, and Bit Size Changes	Minimum Hole Diameter - 3 Inch; Maximum Hole Diameter - 24 Inches; No Restrictions on Casing or Borehole Fluid	Analog Stripchart and/or Digital Magnetic Tape	Hole Diameters Are Needed for Compensation Equations Used on Other Logs; Can Be Run Simultaneously With Other Logs

BEST DOCUMENT AVAILABLE

APPENDIX D

DUTIES OF THE RESPONSIBLE GEOLOGIST

The term "Responsible Geologist" is the result of the Teton Dam hearings, review team reports, and subsequent additions to Reclamation Instructions:

Section 131.03 E requires that there be a Responsible Geologist for each existing or authorized Bureau dam.

Section 131.0.6 A requires that the Responsible Geologist be a member of the Project Team for each dam.

Sections 133.2.2 and 133.3.1 require that the Responsible Geologist be a member of the Damsite and Structure Review Team.

Section 175.3.1 requires that the Responsible Geologist be a member of the foundation acceptance team.

A Division of Geology geologist assigned to the design and specifications of any Bureau structure will be the "Responsible Geologist" for that structure.

A Responsible Geologist will be assigned to <u>each feature</u> being designed and constructed by specifications of the ACER and to other site-specific activities for which the ACER has responsibility. The basic intent of these assignments is to identify an individual geologist who will ensure that all geologic information important to the safety and performance of the facility is accounted for during its design and is implemented and supplemented as necessary during construction. On each assignment the Responsible Geologist is also to provide for geologic technical adequacy, to create a continuity of effort by establishing an organizational and technical liaison during the geologist's involvement on the job, and to facilitate program accomplishment.

The probable sequence of activities and the milestone geologic documents which are authored or reviewed by the Responsible Geologist in a typical

design-construct situation are as follows (in approximate chronological order):

1. Participates in Project Team (dams only) or Design Team review of site and documentation of visit.

2. Prepares the Engineering Geology Review Memorandum. This memorandum shall be written by the Responsible Geologist in coordination with E&R Center designers and materials specialist and in consultation with regional and/or project personnel (see section 3).

3. Collaborates with field geologists, design engineers, and materials specialists in preparation of geologic exploration program including at least:

   a. Exploration primarily intended to answer basic geologic questions, and
   b. Site-specific exploration intended to develop detailed geologic or laboratory test data required for design of specific structures.

4. Reviews and approves the Geologic Design Data Report prepared in the Project or Regional Office (see section 3).

5. Prepares and reviews geologic paragraphs and drawings for specifications (see section 3). These shall be written and prepared by the Responsible Geologist and reviewed by, or under the supervision of, the Regional or Project Geologist.

6. Compiles the "Records of Subsurface Investigations," except those for borrow areas for embankment dams, in accordance with ACER Memorandum No. 31, dated July 27, 1981 (see section 3 and Appendix F).

7. Prepares the Design Summary and Geologic Design Construction Considerations memorandum.

8. Prepares Requirements for Geology during Construction memorandum. The memorandum shall be written by the Responsible Geologist and submitted with the specifications on the SPECB date. It shall define for the Contracting Officer or his representative at the site the geologic documentation or validation requirements during construction.

9. Participates in foundation acceptance teams and documentation of inspections.

10. Reviews and approves Construction Geology Report. This report shall be written by Project or Regional Geologists in accordance with Reclamation Instructions Part 171.6. The Responsible Geologist shall review, approve, and prepare a written response to the region within 20 working days of receipt of the report.

The fundamental role of the Responsible Geologist is to provide on a continuing basis: (1) technical guidance, assurance, and service; (2) field-office-design liaison; and (3) direction for a geologic program.

The technical guidance, assurance, and service function includes the following activities, either direct or supportive, by the Responsible Geologist:

- To actively participate at the E&R Center in the conception and development of investigation, treatment, and monitoring programs involving geology for such items as detailed foundation treatment, grouting, slope stabilization, and instrumentation.

- To recognize and help solve geologic foundation problems involved with engineering design and construction.

- To become personally knowledgeable of the site geologic conditions through appropriate field reconnaissance, interoffice conferences, and personal research.

- To provide technical assistance to all involved parties.

- To maintain knowledge of state-of-the-art geologic and design principles and techniques.

- To ensure the proper recognition of geologic design and construction considerations.

- To participate in foundation acceptance reviews to assure that the foundations are equivalent to the design foundation concept, are compatible with the structures involved, and that ongoing or planned foundation treatment is acceptable, and to recommend additional treatment as necessary.

- To define the need for and to secure technical services.

- To prepare appropriate geologic documents.

- To approve the technical content of geologic documents.

- To prepare and review specifications paragraphs and drawings.

- To review other relevant documents with geologic content.

The field-office-design liaison function includes the following actions by the Responsible Geologist:

- To inform and to solicit opinion from designers, planners, field personnel, and other involved parties or individuals regarding the scope, status, and results of geologic programs.

- To advance communication between all parties involved in a geologic program and promote use of geologic design data.

- To participate in team assignments.

- To maintain a current knowledge of project status and routinely monitor data being obtained.

- To coordinate responses.

- To promote the timely convening of teams.

- To make sure documents receive proper distribution.

The direction function includes the following initiatives by the Responsible Geologist:

- To help formulate a program that will supply needed data within a realistic time frame.

- To define, in conjunction with field personnel, appropriate geologic investigation programs.

- To recommend field staffing requirements.

- To define reporting practices and specifications format.

- To establish the need for independent reviews and technical consultation.

- To provide flexibility to the field programs by the timely evaluation of the data obtained.

- To coordinate interoffice geologic activities, report delays, and recommend reestablishment of flag dates, if necessary.

- To enhance cooperation and coordination between the project, region, and the E&R Center.

The role of the Responsible Geologist was not intended to supplant the inherent responsibility and authority of the organization. However, by directive and procedure, it does imply an individual responsibility for the technical adequacy, completeness, and timeliness of assigned geologic programs. It remains a responsibility of the Responsible Geologist to inform management of critical geologic conditions and to present to them recommendations and geologic information upon which to make decisions.

APPENDIX E
PROTECTIVE EQUIPMENT AND
VISITS TO CONSTRUCTION SITES

This section addresses requirements or guidelines to be used for visits to construction sites. Most Project Construction Engineers have established procedures for visitors. These usually consist of:

1. Inform the Project Construction Engineer or his designated representative of your visit before the trip and notify him in advance if special equipment or assistance will be needed.

2. Make a courtesy visit to the Project Construction Engineer or his designated representative. Explain why you are there, what you will do, how long it will take, and the arrangements for special equipment or help you need.

3. Be familiar with safety regulations concerning the areas you will be in. A Standing Operating Procedures guide for safety is usually available through the field office. It is incumbent upon the visitor to obtain all necessary safety equipment before the visit, or make arrangements to obtain the equipment upon arrival.

4. If unaccompanied, check in with Chief Inspector before going into any active construction areas. Ask questions if you are in doubt concerning any safety procedures, especially those particular to the site.

5. When departing from the site, inform the Chief Inspector or his representative.

6. Advise the Project Construction Engineer or his representative of your findings or conclusions and, if possible, what recommendation(s) will appear in your travel report or followup memorandum.

7. Prepare all travel reports, project team reports, or memorandums with recommendations and conclusions as expeditiously as possible upon your return to the office.

Each employee participating in trips to the field shall have the following personal protective equipment before they are allowed to go on such trips:

1. Prescription or plain safety glasses.

2. Leather-type protective footwear meeting ANSI Standard Z41.

3. Safety helmet. If the employee does not want to carry a helmet, he/she should make sure there is one available at the field office.

The following special requirements shall be conformed to where applicable:

1. Tunnels:

a. All rubber footwear shall have safety toes and flexible puncture-resistant metal minisoles.

b. Each employee shall have "Mine Emergency and Self-Rescuer" training.

c. Each employee shall contact the field office and determine what safety equipment is required in that particular tunnel and if it is available at the tunnel. Any equipment required and not available at the tunnel must be obtained from another source prior to participating in the tunnel inspection.

2. When working around large haulage equipment, public thoroughfares, or large game hunting areas during open season, fluorescent, red or day-glow vest, coat, or poncho must be worn.

3. Occupant restraining systems shall be used in all vehicles. An operator shall not put a vehicle in motion until all occupants are protected by the restraint systems.

4. Personnel working with explosives or radioactive sources or working on steep slopes or situations subject to falls from heights over 6 feet, boats, rafts or skiffs, are cautioned that additional safety rules and equipment are needed. Anyone involved with these materials or conditions shall contact the appropriate safety coordinator for applicable requirements before proceeding.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Engineering and Research Center
Building 67, Denver Federal Center
Denver, Colorado 80225

July 27, 1981

Assistant Commissioner
Engineering and Research
Memorandum No. 31

Subject: Requirements for Records of Geologic and Subsurface Investigations and for Records of Construction Materials and Foundation Materials Test Data to be Furnished to Prospective Bidders

I. Purpose

Field and laboratory data on geologic and subsurface investigations, construction materials, and foundation materials which are gathered during the investigation and design process historically have been compiled and presented to bidders in a number of different ways, such as in a publication titled "Records of Subsurface Investigations and Construction and Foundation Materials Test Data Report." It is the intent of this memorandum to provide direction on the responsibilities and requirements for presenting such information, and typical contents and methods of presentation of such information.

The primary purpose of presenting such acquired data is to furnish prospective bidders with all available information gathered during surface and subsurface investigations and related to construction materials and foundation materials which may be useful to them in preparing their bids. However, the presentation may also be used:

A. By the contractor during construction
B. By Service personnel during and subsequent to construction
C. During dispute settlements and claim litigation

II. Requirement

Records of geologic and subsurface investigations and records of construction materials and foundation materials test data accumulated during the investigation and design process, which are determined to be of potential value to the bidders, shall be incorporated into the specifications. The determination of potential value shall be made by the principal designer and the responsible geologist with input from appropriate personnel and with the concurrence of the line organization.

Logs of exploration in a specifications are important parts of the contract document and may be used as basic evidence in a court of law in case of dispute. Each exploration log, therefore, should be factual, accurate, and complete. However, it is anticipated that the presentation of Records of Geologic and Subsurface Investigations and of Records of Construction Materials, and Foundation Materials Test Data may include professional interpretations of factual geologic and subsurface data, and laboratory test data. When professional interpretations are presented, they should be

BEST DOCUMENT AVAILABLE

carefully identified as such. Interpretation of data normally will not be included on logs of subsurface explorations for borrow areas.

The compilation of data shall begin as early as practicable in the design process, and shall be completed in time to be incorporated into the specifications.

Where an extensive amount of data is to be included (where and appendix to the specifications would have previously been used), the data shall be presented in two new divisions in the specifications:

A. Records of Geologic and Subsurface Investigations
B. Records of Construction Materials and Foundation Materials Test Data

Any special field tests will be incorporated into one of these two divisions.

These new divisions should be incorporated at the end of the specifications. They may or may not be in a separate volume of the specifications depending on the quantity of data involved. In either case, the information will be provided to all who are furnished copies of the specifications.

III. Responsibility

A. The principal designer shall be responsible for:

1. Drafting an outline for "Records of Geologic and Subsurface Investigations" and for "Records of Construction Materials and Foundation Materials Test Data," in conjunction with the responsible geologist, and initiating requests for development and compilation of such information. This initiating request shall be early in the design process, and it is suggested that this request be made as part of the standard memorandum No. DC-681 (see attachment No. 1). This memorandum should include realistic schedule deadlines for the Division of Research. More detailed requests for specific tests or information may follow from appropriate personnel.

2. Updating the outline as necessary during the design process and communicating changes to all appropriate parties.

3. Reviewing the total information package prior to transmitting to the Specifications Coordinator. The review should be to insure the adequacy and suitability of the information presented.

B. The responsible geologist shall be responsible for:

1. Compiling the "Records of Geologic and Subsurface Investigations," except those for borrow areas for embankment dams. (Borrow areas for embankment dams shall be compiled by the Embankment Dams Section.)

C. The Division of Research shall be responsible for:

1. Compiling the "Records of Construction Materials and Foundation Materials Test Data" which should include all available field, consultant, and E&R Center test data.

BEST DOCUMENT AVAILABLE

2. Establishing cutoff dates for reporting of data for item C.1. above, and for compiling subsequent test data to be included by supplemental notice.

D. All of the above responsible parties shall communicate with each other so that the information provided is complete and accurate, but not redundant. The specifications coordinator will combine the various portions of the data from the responsible parties and add appropriate specifications paragraphs for the draft specifications.

IV. Contents

The types of data presented in the specifications will vary in accordance with the specific project. The following typical suggested contents are attached:

Attachment No. 2 - Concrete Dams
Attachment No. 3 - Embankment Dams
Attachment No. 4 - Tunnels
Attachment No. 5 - Power and Pumping Plants, Switchyards, Transmission Lines, and Miscellaneous Buildings

Where required, the contents for canal and pipeline work should be similar to that outlined for Embankment Dams.

These typical contents are not required to be used precisely as shown, nor will all of the various records listed be necessary for each project. It is anticipated that the typical contents will be edited as necessary for each individual project.

Karl Dreiss

Attachments

ACER Distribution

159 BEST DOCUMENT AVAILABLE

Attachment No. 1

REQUEST FOR FINAL DESIGN DRAWINGS AND SPECIFICATIONS PARAGRAPHS

Denver, Colorado
DATE:

TO :

FROM :

SUBJECT: Request for Final Design Drawings and Specifications Paragraphs -
Feature: _____

Project: _____ Units: _____ Region: ____
Job No.: _____

The subject specifications is presently scheduled for coordinating branch release (SPECB date)_____. This specifications will include _____ schedules as follows:

_____
_____
_____
_____

Please furnish draft specifications paragraphs, final signed drawings, schedule items and quantities, your portions of the Records of Geologic and Subsurface Investigations and of the Records of Construction Materials and Foundation Materials Test Data, draft construction considerations, draft design summary, etc., to Code _____ by _____ (date).

Each branch is responsible to keep apprised of current dates as flag dates are revised. Current dates will be reflected in the Denver Office "SPEC" Schedule, I.D. Code _____ .

For information call _____ , Code _____, Ext. _____ .

The following is a summary of work to be included in this specifications.

Copy to:

SUGGESTED CONTENTS

CONCRETE DAMS

Division __ Records of Geologic and Subsurface Investigations

Section 1. Drawings

Section 2. Structure

a. Drill holes
b. Auger holes
c. Test pits

Section 3. Aggregate Sources

a. Drill holes
b. Auger holes
c. Test pits

Section 4. Riprap

a. Drill holes

Section 5. Geophysical data

a. Resistivity
b. Refraction

Section 6. Photographs

a. Site geology
b. Cores

Division __ Records of Construction Materials and Foundation Materials Test Data

Section 1. Concrete aggregate test data

a. Physical properties test data

Section 2. Gradation of aggregate from test pits

Section 3. Riprap test data

Section 4. Rock core test data

a. Absorption, permeability, porosity, and specific gravity properties tests
b. General properties tests, including modulus of elasticity, Poisson's ratio, and unconfined compressive strength

BEST DOCUMENT AVAILABLE

c. Direct shear values
d. Triaxial tests
e. Sliding tests
f. Summary of tension tests
g. Ultrasonic velocity
h. Special tests

Section 5. Petrographic investigations - petrographic examination of rock cores

Section 6. Summary of physical properties tests

SUGGESTED CONTENTS

EMBANKMENT DAMS

Division __ Records of Geologic and Subsurface Investigations

Section 1. General drawings

a. General map
b. Materials distribution

Section 2. Structure

a. Drawings

(1) Locations of explorations (geologic overprints)
(2) Geologic sections
(3) Geologic explanation and notes

b. Drill hole logs
c. Auger hole logs
d. Test pit logs
e. Test trench logs and profile
f. Water level data sheets
g. Pump yield tests
h. In-place density and moisture tests

Section 3. Borrow (to be furnished by the Embankment Dams Section) and aggregate sources

a. Drawings

(1) Locations of explorations for borrow areas
(2) Borrow area sections

b. Auger hole logs
c. Test pit logs
d. Test trench logs
e. Water level data sheets
f. In-place density tests
g. In-place moisture tests

Section 4. Riprap and/or rockfill

a. Drill hole logs
b. Blast tests

Section 5. Geophysical data

a. Resistivity
b. Refraction

Section 6. General photographs

(Prefer to include in appropriate locations above)

BEST DOCUMENT AVAILABLE

Section 7. Referenced data

(Indicate item and location where it can be examined)

Division __ Records of Construction Materials and Foundation Materials Test Data

Section 1. Concrete aggregate test data

Section 2. Riprap test data

Section 3. Soil test data

a. Foundation materials:

Physical properties tests
One-dimensional consolidation test
Expansion and uplift tests
Unconfined compression test
Triaxial and direct shear tests
Soil dispersion and soil chemistry tests
In-place moisture and density tests
Special tests

b. Borrow materials:

Physical properties tests (Proctor)
Physical properties tests (relative) - filter
Physical properties tests (Proctor) - filter
Permeability tests
One-dimensional consolidation tests
Triaxial and direct shear tests
Expansion and uplift tests
Soil dispersion and soil chemistry tests
Special tests

Section 4. Soil cement test data

Physical properties tests
Soil cement tests

Section 5. Petrographic test data

Section 6. Special field tests
Grouting
Test embankments
Irrigation of borrow areas and foundations

Section 7. Referenced data

(Indicate item and location where it can be examined)

SUGGESTED CONTENTS

TUNNELS

Division __ Records of Geologic and Subsurface Investigations

Section 1. Drawings

Section 2. Structure

a. Drill holes
b. Auger holes
c. Test pits

Section 3. Borrow and aggregate sources

a. Drill holes
b. Auger holes
c. Test pits

Section 4. Riprap

a. Drill holes

Section 5. Geophysical data

a. Resistivity
b. Refraction

Section 6. Photographs

a. Site geology
b. Cores

Division __ Records of Construction Materials and Foundation Materials Test Data

Section 1.- Summary - which will include:

a. Brief description of all rock core tests, analyses, and procedures
b. Tabular summary of all test results, petrographic analyses, and aggregate tests
c. Conclusions or results

Section 2.- Detailed reports or data sheets on rock cores or foundation material that will include:

a. Petrographic memorandums including petrographic examination sheets and X-ray diffraction analyses
b. Wetting test data and photographs
c. Afterbreak analyses
d. Free swell tests and photographs
e. Physical properties and structural properties

BEST DOCUMENT AVAILABLE

(1) Elastic modulus
(2) Poisson's ratio
(3) Compressive strength
(4) Ultrasonic velocity
(5) Specific gravity
(6) Miscellaneous
(7) Absorption properties
(8) Direct shear values
(9) Sliding friction values
(10) Tension tests

f. Uplift and expansion tests and plots
g. Concrete aggregate test data reports
h. Miscellaneous reports
i. Bibliography and references as required

SUGGESTED CONTENTS

POWER AND PUMPING PLANTS, SWITCHYARDS, TRANSMISSION LINES, AND MISCELLANEOUS BUILDINGS

Division __ Records of Geologic and Subsurface Investigations

Section 1. Drawings

Section 2. Structure

a. Drill holes
b. Auger holes
c. Test pits

Section 3. Borrow and aggregate sources

a. Drill holes
b. Auger holes
c. Test pits

Section 4. Riprap

a. Drill holes

Section 5. Geophysical data

a. Resistivity
b. Refraction
c. Electrical analogy tray studies

Section 6. Photographs

a. Site geology
b. Cores

Division __ Records of Construction Materials and Foundation Materials Test Data

Section 1. Soils test data - results

a. Triaxial shear and direct shear tests
b. Consolidation and expansion tests
c. Density and water content tests
d. Porosity and permeability tests
e. Alkali-reactive tests
f. Corrosivity and resistivity tests
g. Summary of physical properties tests
h. In-place moisture and density tests

Section 2. Rock test data - results

a. Triaxial tests
b. Hardness tests

BEST DOCUMENT AVAILABLE

c. In-situ stress measurements
d. Riprap tests
e. Shear and sliding friction tests
f. Ultrasonic velocity
g. Modulus of elasticity and Poisson's ratio
h. Unconfined compressive strength
i. Absorption, porosity, specific gravity

Section 3. Concrete aggregate test data